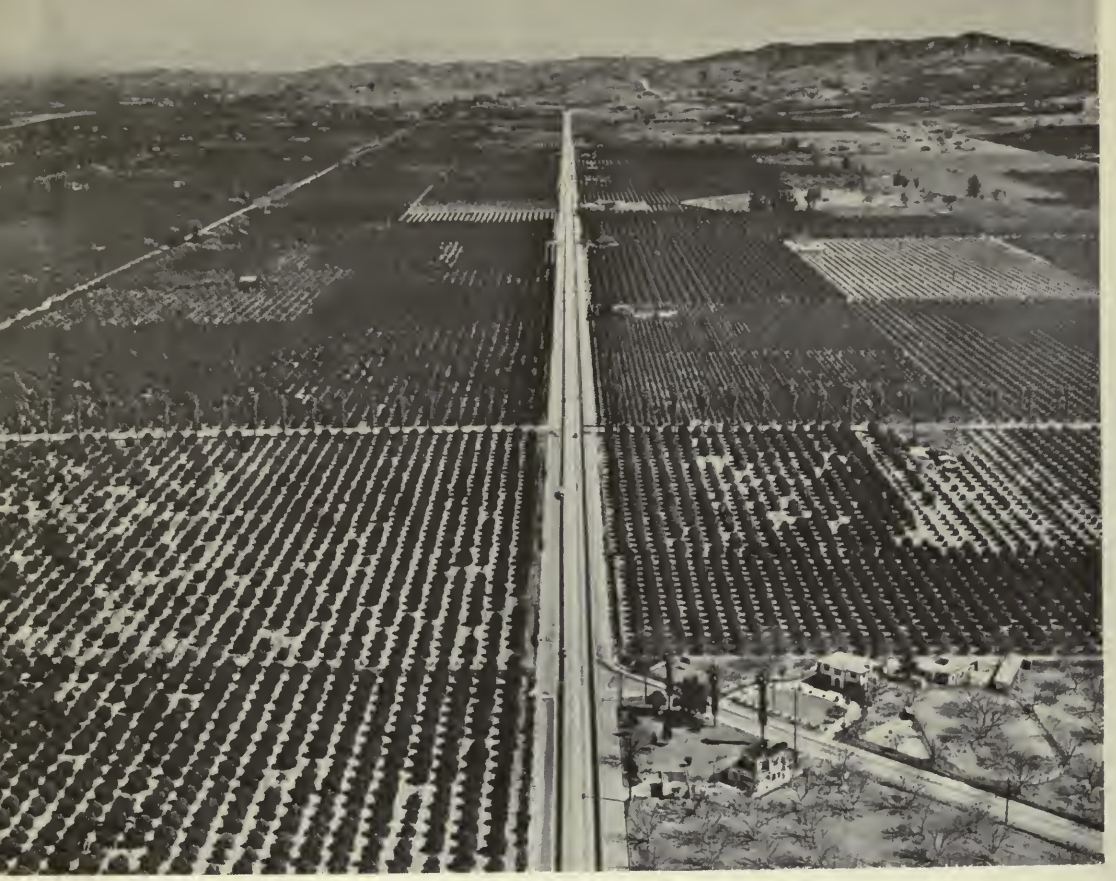
WATER IN CALIFORNIA

S. T. Harding



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WATER IN CALIFORNIA

RECONNAISSANCE
of the
TULARES VALLEY
made by order of Brev. Brig. Gen. Riley.
Commanding 10th Mil. Dept.
by
Lieut. G. H. Derby Top.l Eng.rs
April and May
1850.
Scale
Drawn by Lieut. Derby
TULE
TACHE LAKE
BED OF THE TULE TACHE
SIERRA NEVADA
Monterey
San Juan
Gonzales
Tejon
Kern
Buena Vista Lake
Tulare Lake
Kings River
Fresno
Pueblo de Reyes
Tejon Lake
Tejon Mountain
Tejon Pass
Tejon Ranch
Los Angeles
Santa Barbara
Ojai
San Miguel
Paso de Robles
Santa Margarita
San Luis Obispo
Mt. San Luis Obispo
Mt. Pinos
Mt. Grayson
Mt. Diablo
Mt. Shasta
Mt. Lassen
Mt. Hamilton
Mt. Tamalpais
Mt. Sierra Madre
Mt. Sierra Nevada
Mt. Sierra Blanca
Mt. Sierra Morena
Mt. Sierra Leona
Mt. Sierra Negra
Mt. Sierra Verde
Mt. Sierra Azul

WATER IN CALIFORNIA

by S. T. Harding · CONSULTING ENGINEER

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Preface

While much has been written on the extent of California's water supply and the history of its use, this record has not been assembled in any single source where both the past development and plans for the future have been discussed for the major uses of water. Such a treatment has been attempted here. It is a large order which, under the limitations on length that have been used, must be presented on broad lines without complete detail on any of its parts. The standard sought has been to include sufficient specific information on the history of each use of water to furnish a basis for understanding its extent and its limitations. Too much detail would obscure the main points which need to be emphasized; too little would fail to supply an adequate background to support the conclusions which are reached.

The author's work on California's water supply began in 1911 in the inventory of the water supply and irrigable lands made by the U.S. Department of Agriculture in cooperation with the then California Conservation Commission. His work in this field has been continuous since this beginning. For the record for the period prior to his own experience, reliance has been placed on the visible results of earlier development and the historical records. In the first portions of his own work there was an opportunity to know the then older men who had shaped much of California's earlier progress. The written record is large and relatively complete.

In writing about the last hundred years, there is a natural tendency to emphasize the more recent happenings. These loom large in the present view. Our present problems, however, probably do not appear to be any more difficult to solve than many of the problems which have arisen in the past and have been met so successfully that we now accept the solution reached as a matter of course. In judging the importance of recent events, an effort has been made to see them from the point of view of someone who might be preparing a similar account one hundred years from now. Present matters of personality will disappear, controversies will be settled, and an author in A.D. 2060 will probably be no more concerned with many of these matters than we are now concerned with similar events which may have seemed important in A.D. 1860.

The author does not delude himself with the idea that any book on California's water and its use will settle the present differences of opinion and the conflicts of interest in this field. The elements of local and individual interest which are involved in the development of the waters of the state are too numerous and too diverse to enable human beings to agree completely on their solution. Such self-interest applies to those who will receive service from the future projects; it also includes those who will be employed in the planning and construction of these projects. Perhaps some of those active in the development of the waters of the state may gain a somewhat broader perspective of the whole field from the type of discussion which has been attempted here.

An effort has been made to make all statements factually correct. References have been checked; many historical items have been secured from more than one source. However, detailed reference to all sources that have been used has not been attempted. Sufficient references have been included in the text so that no separate bibliography has been prepared. Sufficient headings have been inserted in the text and included in the Table of Contents to avoid the need for a detailed index.

No work of this kind can be the result of any one individual. Many have helped, both formally and informally. To all of them much appreciation and thanks are due and gladly given. A few had a more definite part. These include my daughter, Helen Harding Bretnor, who helped on many historical matters, and the author's many engineering friends who have helped in numerous ways. Special thanks are due to Bert Smith for reading the manuscript and to Wells A. Hutchins for reading chapter III on "Water Rights and Water Laws." Both made many helpful suggestions. Much of the historical material was found in the Bancroft Library of the University of California. Credit for the pictures used is given in their titles.

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Introduction

Water is California's most valuable natural resource. While the correctness of this statement will now be generally conceded, it was not recognized in the early years of the state. At different times gold, oil, soils, or the general climate have been regarded by many as being more important to California than its water resources. Gold and oil are not renewing resources and will eventually be depleted. The full use of California's soil can be secured only when it is irrigated. The general climate of the state is a major resource but favorable temperature conditions alone will not permit development of an arid area unless it can secure an adequate water supply for its needs. The final limit on the growth which California may reach will be determined by the extent to which its water supply can be regulated, delivered, and used in the areas in which it is desired to use it.

The future utilization of the state's water resources are matters of direct and material concern to every Californian. No Californian can escape being affected both by the extent of the physical development that may be made and by the public policies that may be adopted to regulate and finance our future projects. Sound development and policies can only be secured as a result of active and informed public interest in all phases of this field.

California's history as a state for over one hundred years furnishes a sound background for a review of its water resources, the extent to which they have been used, and the additional development that can be made. While California has progressed far in the use of its water resources, there is much more to be done before their use will be complete. Past developments have been made as need for them has arisen. It is only in recent years that extensive study has been given to the total water resources under a program directed toward securing their maximum utilization.

Studies of the remaining opportunities for development naturally stress future plans rather than past accomplishments. In such looking ahead, sight can easily be lost of the result of what has already been done. California has been a pioneer and a leader in nearly all forms of the use of water. The interest in even greater future leadership should not detract from the recognition of past achievements. In hydraulic mining; reclamation, irrigation, municipal water supply, hydroelectric power, flood control, and inland navigation, California has pioneered in engineering, in construction, in the development of customs and laws for the control of water and title to its use, and in the forms of organization for both the construction and the operation of its water projects. These records of past accomplishments furnish a sound background on which to base future plans.

California's record in the use of its water resources includes controversies between conflicting interests and financial difficulties where developments were made too far in advance of sound demand. These are inherent conditions in the development of any new area. Out of such experiences have come our present laws and customs relating to title to the use of water and an understanding of the practical limitations on the ability of new projects to meet their costs. Disregard of this past record in planning for the future can result in having to relearn the basic limitations established in our past experience.

Until recently, water development in California has been accomplished by the people of the state under their own initiative, working through various

forms of local organization. Outside capital, where secured, was from private sources until the entrance of the federal government into the financing of such projects. Limited federal funds for navigation have been available in accordance with the general national policies in this field. The Boulder Canyon Project was authorized in 1928 and construction began in 1931. Federal funds for irrigation, on a major scale, began to be available for the Central Valley Project in 1935. The extent of federal funds made available in recent years for irrigation and for flood control has made the federal government a major factor in project policies and in the political issues which such funds create. Until recently, the activities of the state have been limited to investigations of proposed projects.

Many problems remain to be solved before the water resources of the state can be fully utilized. Such problems become more involved and complex as the limit of the development is approached. The first project on a stream has only its own problems to meet; the last project, in addition to its own internal problems, has to work out its relations with all of the previous projects on the same stream and reach adjustments under which it can operate. These complications test the earlier principles and practices relating to water supply and water rights, expose any inherent weaknesses, and eventually lead to policies representing a reasonable balance between the conflicting individual and public interests involved.

The Table of Contents indicates the scope of the discussion that has been attempted and the sequence of its arrangement. In order to provide a contrast between early and present conditions, California as it existed prior to its acquirement by the United States is first described. This is followed by chapters on the extent and character of the water and land resources of the state and on the development of the system of title to the use of water which has been used. These background chapters are followed by discussions of each of the major forms of water use and then by discussions of the multiple-purpose projects and basinwide programs now usual in our present larger-scale developments. What this past record may show that can be used to guide our future development is discussed in the concluding chapters.

Important Dates in Development of California's Water Supply

1850 Adoption of English Common Law, including riparian rights
1851 State recognition of rights acquired under local customs
1866 Federal recognition of rights acquired under local customs
1872 Statutes passed defining appropriation rights
1874 First comprehensive report on Central Valley (Alexander Report)
1884 Sawyer Decision restricting hydraulic mining
1886 Final decision in Lux vs Haggin, recognizing riparian rights as superior to appropriation rights
1887 Passage of the first irrigation district act (Wright Act)
1903 Basis of rights in underground water established in Katz vs Walkinshaw
1914 Adoption of Water Commission Act
1921 Investigations for comprehensive plan authorized
1927 Final decision in Herminghaus case, adding to advantages of riparian rights over appropriation rights
1927 Authorizations of appropriations of water by the state and preference to counties of origin
1928 Adoption of Constitution amendment requiring all uses of water to be reasonable
1928 Passage of the Boulder Canyon Project Act
1930 Publication of Bulletin 25—the first state water plan
1935 The Central Valley Project started by the U.S. Bureau of Reclamation
1936 Acceptance by Congress of federal responsibility for flood control
1945 Authorization of complete inventory of land and water resources and a plan for water development
1951 Legislative authorization of state's Feather River Project
1951 Publication of Bulletin 1, Water Resources of California
1955 Publication of Bulletin 2, Water Utilization and Requirements of California
1957 Publication of Bulletin 3, The State Water Plan
1959 Passage of Senate Bill 1106, setting an election in November 1960 to finance construction of state water projects

CHAPTER I

California at the Time of Statehood

A visitor to California prior to 1848 would have found its area almost entirely undeveloped. There were missions and some ranches along the coast and a few settlers, such as Sutter, in the interior. No extensive settlement had occurred and no substantial changes had been made in the prediscovery conditions. While there was a small amount of irrigation, the streams were uncontrolled. Large areas were under water during flood periods and higher lands were regularly dry each year when the moisture from the winter rains had been exhausted. California at this time was a virgin field for the miner, the farmer, or the urban resident.

While only limited settlement had taken place by 1848, there are sufficient descriptive accounts available to enable the presettlement conditions to be understood. It is fortunate that the early inhabitants and visitors in California included many careful observers who have left written records of what they saw. The mission padres and their supporting military forces have left accounts of their expeditions. A surprisingly large proportion of the early American trappers and travelers have also left written accounts. Government-sponsored expeditions made adequate reports. A consistent description of conditions in California prior to its settlement can be prepared from these records.

California is too large and the conditions are too variable for it to be described without using divisions of its area. In matters of water resources the state divides itself naturally at the Tehachapis. As yet water has not been conveyed across this range. Southern California is similarly divided into the inland and coastal areas, although diversions are now made from the inland portion to the coastal areas. North of the Tehachapis, the central valley with its two parts, the Sacramento and the San Joaquin valleys, is the major area. Other portions of the state are the central and the northern coastal areas and the eastern slope of the Sierras.

Land Tenure in 1848

Land tenure in 1848 had progressed much further than acquirement of title to the use of water. About thirty land grants were made by the Spanish government prior to 1822 and nearly 800 by the Mexicans by 1846. These grants covered relatively large areas in southern California and in the San Joaquin and the Sacramento valleys. The grants to individuals were limited to one square league of irrigable land, four of dry farming, and six for grazing, giving a maximum of eleven square leagues. The square league as used in these Mexican grants contained 4,438 acres. There were also provisions for larger grants for colonization projects; a few grants of this type were made but very little actual subdivision and settlement was accomplished during the Mexican period. Ownership in such large tracts facilitated acquiring lands for development and sale in later years after California had become a state. Many projects now operating had their inception in the development and colonization of these land grants.

The Mexican land laws, like those of the United States in its earlier pioneering days, were loosely enforced. When the area in California was acquired by the United States, it was necessary to define the titles and determine the boundaries of these grants. A special procedure was established for this purpose. Those lands for which proof of grant could be established and whose descriptions could be defined on the ground were recognized and their titles confirmed to the grantees. This required much investigation and litigation which extended over many years. Title was finally confirmed by the federal courts to about 600 of these grants having a total area of about 9,000,000 acres.

Early Conditions in Southern California Mission Irrigation

The first irrigation in California occurred at the missions. The earliest irrigation recorded was that from the San Diego River for the San Diego Mission in 1770. The remains of the diversion dam and of portions of the six-mile conduit to the mission can still be found. San Juan Capistrano Mission began irrigating in 1776 and soon had more land so served than is now irrigated there. The San Fernando Mission used water from the adjacent ciénega soon after its founding in 1797. The San Luis Rey Mission followed in 1789 and Pala in 1815. The Mill Creek zanja was built between 1820 and 1830 for lands of the San Bernardino branch mission. There were early diversions from the San Gabriel River for the San Gabriel Mission. After the secularization of the missions in 1833 these systems generally fell into disuse. The Mill Creek zanja passed to the Lugo family and was acquired by the Mormons in 1851 for $7,500. It, or its equivalent, is still in use for similar lands.

Comments on irrigation at some of the missions are included in the Historical, Political and Natural Description of California by Pedro Fages in 1775 as translated by Herbert I. Priestley. The San Gabriel Mission is said to have an abundance of running water so that good results can be had with

wheat, corn, and beans. "The Rio de la Porciúncula contains water sufficient to use for irrigation, as does another copious stream which is further on, some three leagues to the west." The Rio de la Porciúncula is the present Los Angeles River.

The largest amount of mission irrigation was at San Diego and Santa Barbara. The dam on San Diego River was 12 feet high and 245 feet long. The Santa Barbara dam, also of mortar-laid masonry, was 100 feet long and 17 feet high. Conduits diverted from each end to serve a mission vineyard and gardens as well as a grist mill. Portions of the reservoirs used still remain. There was some irrigation at San Gabriel, San Fernando, Soledad, and San Antonio. The works used at the Purísima Mission have been restored in recent years.

Other Early Irrigation in Southern California

The first irrigation in the area that is now Los Angeles began soon after 1770. The Zanja Madre conveyed water to the town from the Los Angeles River. It was later extended and declared to be a public zanja. The order establishing the pueblo in 1781 includes provisions relating to the irrigation of its area. This order was ratified by the California Legislature in 1850, 1852, and 1854. The pueblos of Los Angeles and San Diego have been recognized as having prior rights to the use of the waters of the Los Angeles and San Diego rivers, respectively, which have enabled them to secure first use on these waters for their municipal needs. Such pueblo rights apply only to settlements recognized as pueblos by the Mexican government prior to the acquirement of California by the United States. Some orchards and vineyards were irrigated by the pueblo of Los Angeles prior to 1850. The upper part of what is now the Azusa system was built from the San Gabriel River in 1841. The Duarte ditch, built in 1854 on the west side of the river, has its upper part in the old channel used for Mission San Gabriel.

The Desert Portion of Southern California

Except for the area along the Colorado River there had been little exploration of the southeastern part of California prior to 1848. There had been some irrigation on the Colorado River. Captain Fernando Alarcón had sailed up the river to near Blythe in about 1540. Fort Yuma was established in 1850 and was supplied by boats coming up the river from the Gulf of California. The accounts of Father Kino at the end of the Seventeenth Century and of others nearly one hundred years later indicate that beans, melons, pumpkins, and other crops were grown on the overflow lands of the Colorado River in California across from Yuma and in the Palo Verde Valley.

The irrigation of the Imperial Valley was proposed by Dr. O. M. Wozencraft, who had traveled there in 1849. In the late 1850's a bill was introduced in Congress providing for the construction of a canal to the Salton Sink to create an inland sea with an area of 500,000 acres. It was claimed that the evaporation from such a water area would moderate the climate. Similar evaporation is now occurring from the irrigated areas of the Imperial Valley and from the present Salton Sea without any measurable effect on the local climate.

The first report on Salton Sea was made by William P. Blake, geologist for the 1853 Railroad Surveys. At that time the area of the sea was dry, although some inflow occurred at times as the Colorado River changed the channel conditions on its delta. Blake found the upper portions of a new river which had been formed by overflow from the Colorado River since Emory had crossed this area in 1846.

Fremont included the Mojave River in the Great Basin in his map of 1845

but omitted it in later editions. The 1850 map of the Bureau of Topographic Engineers shows a Mohave River as a continuous stream from its sources to the Colorado River. Blake in 1853 reported that the Mohave River terminated in a dry lake encrusted with soda and salt. This latter report is the correct one as the Mojave River drainage area has no outlet and its irregular surplus runoff evaporates from its playa.

Early Conditions in the San Joaquin Valley

The first known visitor to the San Joaquin Valley, who has left an account of what he saw, is Pedro Fages, who entered the south end through Tejon Pass in 1772 and again entered the north end in 1773. Having seen only the two ends of the valley, Fages assumed that one continuous river existed throughout its length. Father Garcés entered the southern end of the valley in 1776. In the same year Jose Joaquin Moraga traveled up the San Joaquin River from near its mouth, perhaps reaching the mouth of the Merced River. In 1804, Father Martín visited the swamp area near Tulare Lake and found what is now called Atwell's Island near Alpaugh. Moraga, in 1806, changed the previous name for the San Joaquin River (San Francisco River) to the present name used for the valley and the river. Estudillo visited Tulare Lake in 1819 and has left a description of the then conditions; he found swamps extending to the Merced River.

The first American to come overland into the San Joaquin Valley was Jedediah Smith, who camped on the Stanislaus River in February 1827 and in the winter of 1827-28. Peg-leg Smith, Carson, and Ewing Young trapped in the valley in 1829 and 1830. Trappers of the Hudson Bay Company founded French Camp near Stockton as a rendezvous in 1832. In the fall of 1832 Colonel J. J. Warner found a number of Indian villages on the Kings and the San Joaquin rivers and on other streams except the Merced. When he returned late in 1833, he found the valley almost depopulated by an epidemic of remittent fever.

The Tulare Lake area in 1841 is described in the "Narrative of the U. S. Exploring Expedition" by Charles Wilkes of the U.S. Navy. A lake in the present location of Buena Vista Lake is shown having an outlet stream to the ocean near San Luis Obispo. Fremont described the general conditions in his official report of June 1848. The first adequate description of conditions in the San Joaquin Valley is the official report of Lt. Geo. H. Derby in 1850. He summarized his observations as follows: "The Tulare Valley from the mouth of the Mariposa to the Tejon Pass at its head, is about 120 miles in extent, and varies from 8 to 100 miles in width. With the exception of a strip of fertile land upon the rivers emptying with the lakes from the east, it is little better than a desert. The soil is generally dry, decomposed and incapable of cultivation, and the vegetation, consisting of artemisias and wild sage, is extremely sparse." A more definite account of conditions in the upper San Joaquin Valley is that of the geologist, William P. Blake, written in 1853.

While these early accounts were not based on definite surveys, they are in agreement on the general conditions in the San Joaquin Valley prior to its development. There were extensive areas along the valley trough subject to submergence and covered with tules or open water. Kern River supplied water to both Kern and Buena Vista lakes; at times of larger flow, Kern Lake extended to Buena Vista Lake and the latter overflowed into the general swamp area extending north to Tulare Lake. South of Tulare Lake was the Ton Tache which was also a lake whenever the inflow was sufficient to fill it. Ton Tache overflowed to Tulare Lake at higher stages and the area near the present Alpaugh became an island when Tulare Lake approached the stage of its overflow through the present Summit Lake and Fresno Slough to the San Joaquin

River. Along Fresno Slough and along the San Joaquin River to the mouth of the Merced River were large areas of swamp. Crossing this area at times of higher flow was difficult. Further north the swamp areas along the San Joaquin River were less extensive.

Above the swamp area on the west side, the lands were arid with only limited flow from the Coast Range streams. On the east side of the valley, early accounts describe the large flows in several of the tributary streams and comment on the ease with which they could be diverted. Except for the overflow areas of these streams, the east side plains were arid.

At the time of statehood, the San Joaquin Valley had all of the resources for the development that has since taken place but a start had not been made toward their use. The early accounts indicate the character of the development that was needed. The dry plains suffered from lack of water and the trough areas from an excess. The pattern of development that should be used was apparent and has been followed. As use of water on the plains reduced the supplies reaching the trough areas, their reclamation became practicable and has been accomplished.

Early Conditions in the Sacramento Valley

Early Spanish explorers in the Sacramento Valley included Moraga in 1808, who came up the east side of the valley and camped on the lower Feather River. The last Spanish explorer was Arguello, who went up the west bank of the Sacramento River and crossed into the Eel River drainage in 1820. Trappers from the Hudson Bay Company visited the valley in 1814. In 1824 Von Kotzebue, a Russian, took boats up to Freeport. Jed Smith was in the valley in 1826 and in 1827. Ewing Young was marooned by floods in 1832 while trapping in the valley. J. J. Warner was a member of Young's party and has left a graphic account of their experiences. He ended his account by stating "Finally after a month's experience of amphibious life, the party reached the dry land of the Putah River, leaving behind a deluged world in which for weeks it had wallowed."

The first official American expeditions in the Sacramento Valley were those of Commander Charles Wilkes and of Lieutenant Emmons in 1841. Both reported unfavorably on the conditions they encountered late in that year. There had been an eleven-month drought and, crops having failed, the inhabitants were living upon their cattle.

Lieutenant George H. Derby reported on the result of an expedition in the Sacramento Valley in 1850. He traveled over the east side of the valley as far north as the Buttes, in October, and found the plains dry. He was caught between Sacramento and Benecia in November in a flood from Putah Creek and lost his wagons but saved his mules and records. He described the general conditions on the west side of the valley as follows: "The valley of the Sacramento on the western bank of that stream, is for the most part a barren plain, with little vegetation or water. It is from thirty to forty-five miles in extent, being bounded on the west by the coast range of mountains. There are no streams emptying into the Sacramento River from the west, south of latitude $39\frac{1}{2}^{\circ}$ north with the exception of 'Puta' and Cache Creeks. This latter is the outlet of Clear Lake, flowing from its southeast extremity, and losing itself in the 'Tule' swamp which borders the western bank of the Sacramento about six miles southwest of the mouth of the Feather River. 'Puta' Creek rises in the Coast Range, and flowing southeast, empties into the Sacramento about fifteen miles below the mouth of the American River. The whole country between the Creeks is liable to overflow, and is very dangerous to attempt travelling after a heavy rain. The 'tule' swamp upon the western bank of the

Sacramento, extending to the vicinity of 'Butte' Creek, and occurring occasionally above, is from three to six miles in width, and is impassable for six months out of the year."

In 1848 the Sacramento River was a clear stream with navigable depths to Sacramento of nine to thirteen feet. The tidal fluctuations at Sacramento were fully two feet with some tidal effect extending as far as the mouth of the Feather River.

In 1848 the Feather River was also a clear stream with a well-defined channel. It had a rocky bed near the mountains and flowed to the mouth of the Yuba over rapids one to two feet deep or pools ten to twenty-five feet deep at low water. Below the mouth of the Yuba the bed consisted of fine gravel or sand bars with long reaches eight to fifteen feet deep at the low stages. There was a low bank on the west above Yuba City through which flood waters escaped to the Sutter County Slough. Yuba City and Marysville were on higher lands above the flood plain.

The trough areas in the Sacramento Valley start a few miles below the mouth of Stony Creek. Above this point the stream gradient is steeper, the valley narrower, and the river remains within a relatively narrow area. In Colusa County there was a tule strip about six miles wide and eighteen miles long in Colusa Basin and about 15,000 acres of overflow land in Butte Basin. Along the river the timber was about a mile wide.

Of the 2,500,000 acres of valley land in the Sacramento Valley, over 1,000,000 acres were subject to overflow in major floods and 500,000 to 750,000 in ordinary floods. The Delta was similarly subject to overflow and its reclamation had not been begun.

Prior to 1848 there was practically no use being made of the resources of the Sacramento Valley. Then, as now, the valley was subject to heavy floods which overflowed from the channel of the Sacramento River. In such overflow the silt carried by the flood waters had been deposited on the overflow banks until the stream channel was above the elevation of the lands in the adjacent trough areas. Flood waters entering these troughs were detained there until the passing of the floods permitted them to drain back to the river at the lower ends of these side basins. While these trough lands were subject to submergence by the flood waters of the winter and early summer, later in the year they became dry like the adjacent plains.

All of the present water and soil resources of the Sacramento Valley were available in 1848. The ability to produce dry-farmed grain has resulted in a slower development of irrigation than has occurred in the more arid San Joaquin Valley, although much has been accomplished both through reclamation from excess water and through irrigation.

Other Areas

There are few early reports on conditions in the other parts of the state, although their general geography had become known. The principal passes in the Sierra were in use to the extent then needed. Although the location of the eastern boundary of California was indefinite, the general character of the mountain valleys on the eastern slope of the Sierra was known. Walker and others had traveled along the eastern side of the Sierra from Walker's Pass northward and left general accounts of its character.

The northern coastal area had been visited by trappers. They generally traveled along the coast and were more concerned with finding routes they could use to get through than in making general explorations. This area then, as now, was relatively more humid than the remainder of the state. Its vegetation was more dense and its topography lacked broad open valleys. This

area has changed less from its original condition in 1848 than other comparably large portions of the state.

The general geography of the northern boundary of California had become known from the travels of trappers and others. The Klamath Lakes and Goose Lake had been described. In these remote areas settlement had not started in 1848.

In the central coast area the principal settlement was around the missions and at Monterey with large ranches producing cattle for their hides and tallow. The Spanish and Mexican influences still prevailed.

Summary

The preceding description of conditions in California in 1848 outlines the potentialities that existed at the time of statehood, although there was little appreciation at that time regarding what could be accomplished in their development. While the raw materials were all present in 1848, California had not advanced to the point where the available population could make any real start on their use, much less have any real understanding of their extent. When this picture of California, as it existed prior to the discovery of gold, is contrasted with the present conditions a little over a century later, a better realization of what the pioneers and their successors have accomplished can be secured than is obtainable by looking at the present results alone.

CHAPTER II

Water and Land Resources of California

Average conditions for the whole state have almost no meaning when applied to its water supply. Practically all extremes can be found somewhere in the state. Precipitation varies from as nearly zero as nature ever achieves to over 100 inches per year in favored coastal or mountain areas. Temperature ranges are similarly wide. The growing season varies from two to three months at high elevations to twelve months in parts of southern California.

The runoff resulting from these widely varying climatic conditions necessarily varies even more widely. Many areas, receiving precipitation only from occasional storms, produce only cloudburst types of stream flow. Other areas receive the larger part of their usually high rate of precipitation as snow and may have a mean annual runoff in excess of three feet in depth over their drainage areas. Natural storage, where the snowfall of the winter season does not melt until within the following crop season, thus meeting irrigation demands during the early months of the crop season without the construction of reservoirs, is a major item in the utilization of many of the Sierra streams.

Records of the water supply of the many streams in California were not obtained in the earlier years of statehood. There was then no equipment or personnel available for making such measurements. Their importance had not

come to be recognized by the public and the state and federal governments had not accepted responsibility for securing continuous measurements of stream flow. Each early water project had to base its plans on the fragmentary information that might be available. Both overestimates and underestimates for individual projects were a natural result of this situation. Gradually the importance of such records came to be recognized and provisions for obtaining them were made. The present extent of measurement and the accuracy of the records represent the results of continuing improvements over earlier practices. Further improvements are still being made in the extent and accuracy of such records.

The first records relating to the water supply of a newly settled area are usually observations of rainfall. The general interest in the rainfall leads some individuals to measure its amount, followed by observations by public agencies. This has been the experience in California. Records of precipitation are available at a few points of early settlement since 1849. Observations were made at the stations along the railroads as they were built. These were followed by the regular and voluntary stations of the U.S. Weather Bureau distributed over the state. Indirect records have been used to estimate the rainfall of earlier periods. H. B. Lynch in "Rainfall and Stream Run-off in Southern California since 1769" has interpreted the mission records of crop yields to develop an estimate of rainfall since 1780.

The present records of precipitation are generally adequate in length so that the annual means and the extent and character of the annual variations within a reasonable range of certainty can be determined. Such records are available at a sufficient number of points in the state to provide for the usual needs for such information.

Records of the precipitation are only an indirect measure of the water supply available for diversion from streams. Much of the precipitation remains on the area on which it falls and is used by the vegetation growing thereon. There is no fixed relation between rainfall and runoff. For areas of flat slope, absorbent soil, and dense vegetation practically all of the precipitation may be retained with only a negligible amount of runoff. On steep areas, with rock outcrops or shallow soils receiving heavy precipitation, the runoff may reach or even exceed three-fourths of the precipitation. Even the driest desert areas occasionally receive cloudburst type storms from which at least some runoff will occur. Similarly, even the highest mountain areas receiving heavy precipitation mainly in the form of snow lose part of the moisture received in evaporation from the snow or transpiration by whatever vegetation may have adapted itself to exist under such conditions.

Runoff is almost never uniform over any substantially large areas in California. Starting in the valley lands of the San Joaquin Valley, the flat slopes of absorbent soil receiving limited rainfall have practically no runoff. Ascending the western slopes of the Sierra, the mean annual rainfall increases. In some areas this increase is at a rate of about one inch per year for each 200 feet of increase in elevation. This rate may continue to elevations of 5,000 or 6,000 feet with little further change at higher elevations. In ascending the slopes of the Sierra, the vegetation varies from sparse grass in the drier lower areas through brush and scrub timber, merchantable timber, and eventually to the timber line. Soils vary from great depth in the valley fills to shallow depths in the adjacent plains, residual soils of varying depth in the middle elevations, and much bare rock at higher levels. The slopes vary from very flat in the valley through increasing rates to the very steep higher mountains. Under these conditions sufficiently detailed and extensive observations of the factors affecting runoff cannot be made to enable the runoff of any of

these drainage areas to be derived dependably except by direct records of its actual amount. In parts of the humid eastern states conditions are sufficiently uniform so that fairly definite relationships may exist between rainfall and runoff which can be applied to the entire drainage areas of some streams. In California such uniformity is absent and direct measurement of the flow of each stream is essential.

A characteristic of the flow of the streams draining the higher portions of the Sierra Nevada is the diurnal fluctuation resulting from melting snow. Snow melting occurs principally from 9 a.m. to 3 p.m. The increased rate of runoff at the snow level during the hours of melting reaches the lower valley at various times, depending on the length and grade of the stream channels. The hourly flow may vary from 125 to 75 percent of the daily mean during the early summer months. This type of fluctuation was recognized as early as 1853 by William P. Blake and mentioned in his report on the Railroad Surveys of that year. Blake was at Fort Miller on the San Joaquin River in July 1853. He comments:

"The river was not at its highest stage at the time of our visit; but a large body of water was flowing in the channel, and it was evident that a considerable quantity of snow remained in the mountains at the sources of the river. A diurnal rise and fall of the water was constantly observed, and is, without doubt, produced by the melting of the snow during the day."

Some direct records of stream flow were secured by those responsible for the early mining projects in California. These were incomplete, usually for short periods, and based on the particular interests of the projects involved. An example of this is the record of draft and waste from Bowman Reservoir from 1872 to 1882, published in Bowie's Hydraulic Mining in California.

Public recognition of the need for knowledge of the extent of our water supply developed during the decade from 1870 to 1880. Hydraulic mining had become extensive, new projects were being considered and the conflict in interest between such mining and agricultural uses in the lower valleys had developed. Irrigation had become sufficiently extensive on many streams so that the demand at the low-water periods was beginning to exceed the supply and questions of the relative rights of different canal systems were becoming important.

When need for some new governmental activity arises, the actual stimulus for its definite beginning is frequently the result of the energy and insistence of some interested individual. This was the case in California. The office of State Engineer was created in 1878 and given the duty of determining the water supply of the state. This action was largely the result of the efforts of William Ham Hall, who became the first State Engineer. He organized a staff of limited size and undertook measurements on the larger streams of the state. Judged by present standards, much of this work was deficient in completeness and accuracy. Judged, as it should be, by the standards of its own times, this earlier work of the State Engineer was an outstanding contribution to the knowledge of the resources of the state. William Ham Hall had as his principal assistant handling stream records C. E. Grunsky, who, for many years, was one of the most distinguished and respected engineers in the state.

State Engineer Hall was able to maintain interest in his work and obtain funds for its continuance from the Legislature for six years. His plans and the work he undertook were ahead of the public thinking of the time. By 1884 legislative impatience with his failure to complete his reports resulted in a reduction in the appropriations for his office. Some reports were completed and published but the records of stream flow were stopped.

The demand for records of stream flow, not only in California but in the

country generally, became sufficiently insistent that the federal government entered this field. The U.S. Geological Survey had been investigating western natural resources, including lands and waters as well as minerals, since its organization in 1879. Much of its earlier work in the western states had been started by Major John W. Powell. Later work in stream measurement was largely the result of the interest of Frederick H. Newell and Arthur P. Davis. Records of stream flow on a basis that was the forerunner of present practice began to be obtained on the more important streams between 1890 and 1900. Continuous records of daily stream flow are now available on several California streams for periods exceeding fifty years.

History illustrates the increasing recognition of the importance of a knowledge of the extent of our water resources and the extent of the work required to obtain adequate records. In the earlier years of such work it was generally considered that a record for five years on a stream would include a sufficient range of its fluctuations to furnish an adequate basis for planning water projects. For eastern areas the probability that a five-year period of record will cover the high and low flows that will occur is much greater than is the case of streams in arid areas. It is now recognized that stream records should be obtained continuously and that no period can give full assurance that longer records may not have flows outside the range of past records. The chance that we may have either floods or droughts outside those shown by past records decreases with the length of the record but never entirely disappears. A record of fifty years furnishes a sound basis for water projects; shorter periods increase the probability that greater floods or more extended droughts may occur for which provision may not have been made in the project plans.

We now have a reasonably adequate knowledge of the water supply of California. While this knowledge will not prevent future errors in details, water development projects in this state can now be undertaken with the assurance that if care and experience are used in determining their available water supplies, the expectations of such projects can be realized. There is now more danger that the water supplies for future projects will fail to meet the project needs as a result of unwillingness to study thoroughly the records now available or to fail to heed the results of such studies than there is from deficiencies in the records themselves. While the promotional instinct of the pioneer and the optimism that neglects to face all of the facts are natural human traits that may be required in the development of new areas, California has now passed its pioneering stage, and thorough investigations, with acceptance of their factual results, are a necessity in present and future projects.

Precipitation

Until recently the annual reports of the U.S. Weather Bureau included an average depth of precipitation for California for each season. This is the unweighted average for all records without consideration of their distribution over the state. Such an annual mean has been published for the years since 1897. The mean for the 59 years 1897 to 1955 has been 23.88 inches per year, varying in individual years from 36.88 to 11.56 inches. This is an annual variation of over three to one. The seven years 1928 to 1934 had a mean annual precipitation of 78 percent of the 59-year mean, and the eight years 1904 to 1911 had a mean of 122 percent of the long-time mean. These results represent the average variation for the whole state. Individual stations have much wider variations.

The precipitation in California occurs mainly in the seven months from October to April. The mean monthly precipitation for the entire state is as follows:

	Inches		Inches		Inches
July	.08	November	2.50	March	3.65
August	.11	December	3.97	April	1.72
September	.39	January	4.72	May	.92
October	1.26	February	4.23	June	.33
				Year	23.88

Eighty percent of the annual precipitation occurs in the five months November to March.

In the north coastal area the mean annual precipitation at individual observation stations varies from about 15 inches in some interior valleys to as much as 60 inches near the coast. Records at stations in the higher elevations are not complete; maximum amounts of mean annual precipitation in excess of 100 inches are indicated at some locations.

In the Sacramento Valley the precipitation varies from about 16 inches in the southern part to about 25 inches toward the northern end. On the tributary drainage area it exceeds 60 inches on some higher mountains and is about 12 inches in some parts of the upper Pit River valley. The San Joaquin Valley receives about 6 inches on the southern valley floor and 15 inches in the San Joaquin delta. For the adjacent Sierra it varies generally from 20 to 50 inches.

The central coastal area has a precipitation varying generally from about 10 inches in inland valleys to 15 to 25 inches along the coast, with some locations in the coastal mountains exceeding 70 inches. The south coastal drainage area receives about 40 inches of precipitation on a few favorably situated higher areas. On the valley lands it varies from 10 to 20 inches.

In the Great Basin areas in California the precipitation varies from about 10 inches in the valleys to about 30 inches in the mountain locations at which records have been kept.

In the southeastern desert basins precipitation is generally small but widely variable. The minimum record for any station in California maintained by the U.S. Weather Bureau is 1.66 inches at the Greenland Ranch in Inyo County. The next smallest measured precipitation is 2.57 inches at Brawley in the Imperial Valley; amounts exceeding 15 inches are received at a few higher stations in this generally desert area.

In Bulletin 1 of the State Water Resources Board a mean annual precipitation for the state of 22.7 inches was derived by plotting lines of equal precipitation and measuring the areas between such isohyetal lines. Applied to the total area of the state of 101,000,000 acres, this annual mean represents a gross precipitation of about 190,000,000 acre-feet per year.

Disposal of Precipitation

Precipitation on any area may be used for transpiration by the vegetation growing on the area, may be evaporated from the soil or water surfaces on which it falls, may be absorbed by the soil and percolate to the underlying ground water, or it may become surface runoff. In some areas the precipitation may be sufficient to support profitable dry-farm agriculture. While penetration of precipitation to the ground water occurs in some California areas, the larger part of the absorbent areas where such penetration might occur receive insufficient rainfall to supply the moisture-holding capacity of the upper soil. The principal sources of water supply available for development in California are the surface flow of the streams and ground water resulting from absorption from stream channels.

Surface Runoff

No one term expresses the total water supply in a form that measures its usefulness. The mean annual volume of runoff is a useful figure and is a general index of the total supply that is available. This volume alone does not indicate the variations from year to year or within the year. It does not indicate the time of occurrence of the runoff in relation to the time of the demand for its use for different purposes.

Also the mean annual runoff does not represent the water supply which can be made available for use. Storage is required to bring the supply and the demand into time agreement. With sufficient storage, the runoff, whenever it may occur, can be regulated to fit the demand for its use. Such storage means costs for construction of reservoirs, which must be balanced against the value of the use of the storage.

Storage necessarily results in evaporation losses and prevents 100 percent usefulness being reached on any stream. The cost of storing the less frequently occurring portions of the runoff usually exceeds the value of its use, so that complete storage regulation is seldom economically feasible. Even where the costs of storage construction may be relatively low, the long periods of carryover storage required results in losses by evaporation. For the generally variable flow of California streams, development for beneficial use of over about 85 percent of the mean annual runoff is seldom economically feasible.

Two extensive inventories of the total water supply of the state have been made by the State Engineer. These inventories were both made as a part of investigations seeking to develop plans for the development of the water resources of the state. An inventory prepared in 1922 was published as Bulletin no. 5 of the then State Division of Engineering and Irrigation. A second inventory has been published as Bulletin 1 of the State Water Resources Board, issued in 1951.

In Bulletin 5 the results are based on the annual means for the fifty-year period 1871-72 to 1920-21. Direct records were not available for many streams for the earlier years of this period. Estimates were made based on precipitation and comparison with other streams having longer records. The results of this work were used in preparing the plans for the Central Valley Project.

Beginning in 1945 the California Legislature has authorized and appropriated funds for making inventories of the state's land and water resources and outlining a program for their development. Bulletin 1 of the State Water Resources Board is an inventory of the extent of the surface and underground water supply of the state, discussed for each of seven major hydrographic divisions of its area. The results are expressed in terms of the estimated or measured annual means for the fifty-three-year period 1894-95 to 1946-47. As actual records for the earlier years of this period were much less extensive than those that have been secured in recent years, the results, where records were lacking, were derived by similar comparisons with the actual available records to those used in Bulletin 5. The results represent as complete an inventory of the mean annual water supply of the state as the then records could provide. It is not probable that additional records will modify these results to any essential extent.

While it is not the purpose of this discussion of the water supply of the state to present detailed statistics on its amount, some results have been assembled to meet the interest of those who may desire to have an overall picture of its location and extent. For this purpose, results from these State reports have been summarized in the following discussion.

The estimated mean seasonal natural runoff of California streams for the fifty-three-year period 1894-95 to 1946-47 as derived in Bulletin 1 is shown in

Table I. This natural flow was defined as the flow of the streams unaltered by diversion or storage of their water or by importation from other drainage basins. This is equivalent to the stream flow prior to its use for any present development. It included generally only the runoff from mountain and foothill lands. For the Sacramento Valley, however, the runoff from the precipitation on the valley floor was included in the estimated runoff.

TABLE I
SUMMARY OF STREAM FLOW OF CALIFORNIA
Results Derived for 53-Year Period 1894-95 to 1946-47 in Bulletin 1 of State Water Resources Board

Portion of State	Gross Drainage Area Square Miles	Natural Stream Flow Mean Annual Acre-feet	Average Runoff Acre-feet per Square Mile	Percent of Total Runoff of State	Percent of Total Area of State
North Coastal	19,600	28,886,000	1470	40.7	12.4
San Francisco Bay	4,400	1,245,000	283	1.8	2.8
Central Coastal	11,300	2,448,000	216	3.5	7.1
South Coastal	11,000	1,227,000	111	1.7	6.9
Central Valley					
Sacramento River Basin	26,900	22,390,000	835	31.6	17.0
Tulare Lake Basin	16,500	3,313,000	200	4.7	10.4
San Joaquin River Basin	11,800	6,386,000	540	9.0	7.4
Delta Tributary Areas	4,200	1,547,000	368	2.2	2.7
Total, Central Valley	59,400	33,636,000	565	47.5	37.5
Lahontan	32,900	3,177,000	96	4.5	20.8
Colorado Desert	19,700	179,000	90	0.3	12.5
Total for State	158,300	70,798,000	450	100.0	100.0

The inventory of the state's water supply in Bulletin 1 was based on a greater extent of direct record than was available when Bulletin 5 was prepared. The areas into which the state was divided were similar but had sufficient differences so that the results in the two reports are not completely comparable.

In Bulletin 5 the mean annual runoff derived from the drainage areas producing the runoff (80,825 square miles) was 72,531,350 acre-feet. This is comparable with the results in Bulletin 1 of 70,798,000 acre-feet from 106,025 square miles of mountain and foothill drainage area. As the difference in the extent of the drainage areas used in these two reports was largely in the meagerly productive Great Basin and Colorado River drainage areas, these two results are generally consistent. The use of records for the additional 26 years in Bulletin 1 furnishes better support for its results without materially altering the numerical results in Bulletin 5.

While California has less interstate stream flow than most of the western states, it receives inflow from Oregon and has outflow to Oregon and Nevada through streams draining into these states. On the Oregon line, California receives a mean annual unimpaired supply of nearly 2,000,000 acre-feet from the Klamath River. About 300,000 acre-feet per year are received from the drainage area of Smith River in Oregon and about the same amount of runoff from the Rogue River drainage area in California flows into Oregon. Along the

Nevada border, streams rising in California discharge about 1,300,000 acre-feet per year into Nevada, principally from the Truckee, Carson, and Walker rivers, and about 200,000 acre-feet per year of Nevada runoff drains into California. These amounts of runoff originating in Oregon and flowing into California and the amounts originating in California and flowing to Oregon and Nevada are included in the total runoff shown for California in the north coastal and Lahontan areas in Table I. California received about 800,000 acre-feet per year more undepleted runoff from these other states than the outflow from California.

The estimated mean annual runoff from valley and mesa areas is not included in the results for the separate parts of the state shown in Table I except for the Sacramento Valley. The total area of the valley and mesa lands in the state, as given in Bulletin 1, is 33,400,000 acres, of which 6,200,000 acres are in the Sacramento Valley. The estimated mean annual precipitation on the total area of valley and mesa lands was 32,400,000 acre-feet, or an average depth of about 12 inches. For these areas, exclusive of the Sacramento Valley, the estimated mean annual total precipitation on 27,200,000 acres was 21,150,000 acre-feet, an average depth of precipitation of 9.3 inches. From these valley and mesa lands some runoff occurs at times of heavy precipitation. As the runoff of these areas generally reaches the streams below the available reservoir sites, the regulation of the runoff from the valley and mesa lands will be difficult and expensive.

To complete the inventory of the total surface water supply of the state, some mean annual supply should be added to the results shown in Table I, to represent a general estimate of the surface runoff which may occur from valley and mesa lands below the points of measurement of the stream flow shown in Table I. Such an item is relatively small.

While California contributes very little runoff to the Colorado River, it makes diversions from its flow. Both the total runoff of the Colorado River and the portion which may be available for use in California have been the subject of extensive study, litigation, and varying conclusions. The mean annual inflow to Boulder Canyon reservoir has been estimated to be about 15,000,000 acre-feet. Under the terms of the Colorado River Compact the upper basin states are to deliver 75,000,000 acre-feet to the lower basin during each ten-year period. Until development in the upper basin, states may utilize the portion of the flow assigned to them under the terms of the compact, the lower basin has received and will continue to receive more runoff from the upper basin than these upper states are required to deliver.

Under the terms of the Boulder Dam Act, California has agreed to limit its diversion from the Colorado River to 4,400,000 acre-feet per year plus a part of any total runoff in excess of 15,000,000 acre-feet per year that may be found to be available for division among the lower basin states. The total supply California will receive from the Colorado River is estimated in Bulletin 3 of the State Water Resources Board as 1,212,000 acre-feet for use in the south coastal area and 4,150,000 acre-feet for use in the Colorado Desert area, a total mean annual supply of 5,362,000 acre-feet.

Adding the total mean annual runoff shown in Table I of 70,798,000 acre-feet and the 5,362,000 acre-feet of expected supply from the Colorado River gives an indicated total surface water supply for the state of about 76,000,000 acre-feet. With an allowance for some additional runoff from valley and mesa lands, California appears to have a mean annual surface water supply of about 77,000,000 acre-feet.

As previously stated, the weighted mean seasonal precipitation for the whole state, derived in Bulletin 1, was 22.7 inches, which, applied to the 101,000,000

acres in California, represents a total volume of precipitation of about 190,-000,000 acre-feet per year. Of this total, 32,400,000 acre-feet were estimated to fall on the 33,500,000 acres of valley and mesa lands whose runoff was not generally included in the runoff through natural surface channels. This leaves about 158,000,000 acre-feet of precipitation on the drainage areas producing an estimated mean annual runoff of 70,800,000 acre-feet. These results represent a mean runoff of 1.05 feet in depth from these drainage areas equal to 45 percent of their mean precipitation.

These results also represent a mean annual retention on these drainage areas of about 87,000,000 acre-feet equal to an average depth of about 1.3 feet. This retention represents the consumptive use of the vegetation on these areas and the evaporation from the soil, water, and snow surfaces.

Table I illustrates the wide variation in the water-yielding capacity of the different parts of the state. Along the coast the average runoff per square mile of drainage area above the valley and mesa lands in the north coast is nearly four times that of the similar area around San Francisco Bay and six times that of the south coast. The rate of runoff in the Sacramento drainage area is more than double that of the San Joaquin. The runoff of the Great Basin area in Table I is not representative of that for the whole basin, as the streams listed drain the higher eastern slopes of the Sierra in California, which have much higher rates of runoff than the entire drainage areas of these streams.

Many reports have commented on the large proportion of California's water supply which comes from its northern areas. Table I shows that nearly three-fourths of the total stream flow of the state comes from the 30 percent of the area of the state in the north coastal area and the Sacramento River basin, leaving less than 30 percent of the total to come from the remaining 70 percent of the state's area.

Within each of the divisions of the state shown in Table I, there are also wide variations in the rate of runoff. While the average annual depth of runoff for the Sacramento basin is 24.1 inches, that for the McCloud River drainage area above Baird is 38.5 inches and that for the Pit River above Canby is only 3.4 inches. In the San Joaquin Valley, the depth of runoff from the larger Sierra streams varies from about 6 to 23 inches, while that from the west side streams varies from one to two inches. In Bulletin 1 the average annual depth of runoff of Smith River near Crescent City is 80 inches; for Mattole River near Petrolia it is 82.5 inches, while for Shasta River near Yreka, which is an inland tributary of Klamath River, it is only 4.7 inches. In the south coastal area the different streams have depths of mean annual runoff of from 18 to 0.7 inches; for the higher drainage areas in the Lahontan area, the similar range is from 33 inches for Donner Creek to 4 inches for Susan River. For the Colorado Desert area, the surface runoff is less than half an inch in depth per year.

Annual Variations in Runoff

Table I is in terms of the mean annual runoff. Just as such means vary widely in the different parts of the state, the runoff of any drainage area varies widely from year to year. Variations in the annual precipitation have been discussed; such variations produce an even greater variation in the runoff. Table II illustrates the extent of the variations in annual runoff for typical streams in the same six divisions of the state that were used in Table I. Table II indicates that in some individual years the runoff may be from twice to four times the mean, the largest ratios occurring in the parts of the state having smaller amounts of runoff. Similarly, in other individual years of de-

ficiency the runoff may be only one-third to one-twenty fifth of the mean. For the ten years 1927-28 to 1936-37 the runoff was less than the mean in all years, with a ten-year average of 69 percent of the mean.

TABLE II
VARIATIONS IN ANNUAL RUNOFF

Illustrations from Records of Typical Streams
Selected from Bulletin 1, State Water Resources Board

Area and Stream	Depth of Annual Runoff in Inches			Percent of Mean	
	Mean	Maximum	Minimum	Maximum Year	Minimum Year
North Coastal					
Eel River at Scotia	31.3	62.0	6.0	198	19
San Francisco Bay					
Alameda Creek	3.5	10.5	0.4	297	11
Central Coastal					
Salinas River at San Lucas	3.4	9.9	0.2	290	6
South Coastal					
San Gabriel near Azusa	10.9	36.4	0.9	334	8
Central Valley					
Sacramento River near Red Bluff	17.2	32.6	6.2	190	36
American River near Fair Oaks	27.0	56.4	5.3	208	20
San Joaquin River above Friant Dam	20.8	47.0	5.1	226	23
Kern River near Bakersfield	5.7	15.2	1.5	267	27
Lahontan					
Susan River near Susanville	4.0	17.9	.3	445	7
East Fork Carson River near Gardnerville	16.0	29.5	7.0	185	44
Entire State	12.6	24.0	3.3	190	26

The extent of the floods that may occur are discussed later in the chapter on flood control. In some years the precipitation is excessive over much of the state and all streams in such areas have large runoff. Years of this type in northern California include 1862, 1907, 1938, and 1955. In southern California similar excessive runoff occurred in 1916, 1922, and 1927. In the San Joaquin Valley 1906 and 1938 are the years of generally maximum runoff of record. Not all parts of the state have had the maximum volume of runoff in the same years. The maximum peak flows result from individual storms. While they occur usually in years of generally large volume of runoff, maximum peak flows and maximum annual volumes of flow may not occur in the same years.

Single years and sequences of years of deficient runoff are also a characteristic of California's climate. The years 1928 to 1934 represent the most severe period of deficiency since stream flow records have been obtained. From 1895

to 1904 there was a severe drought in southern California. The single seasons of greatest deficiency throughout the state since direct records have been secured were 1923-24 and 1930-31.

There are also records of early droughts. The year 1851 was dry and feed for stock was deficient; similar conditions occurred in 1856. In 1864 grain generally failed and stock was lost for lack of feed. Other droughts occurred in 1870-71 and 1876-77. There were large crop and stock losses in 1877, although the drought was less severe than in 1864.

W. T. Ellis, in his Memories—My 72 Years in the Romantic County of Yuba, reports early droughts as well as floods. He quotes a clipping reporting twenty-two months from 1828 to 1830 when the drought at Monterey resulted in the wells and springs becoming dry so that water had to be brought from the Carmel River for use in Monterey.

General John Bidwell has described conditions in the Sacramento Valley in two early dry seasons. He states,

"In the Fall of 1841 the country was without bread because of the preceding dry Winter. What little wheat there was had to be saved for seed.

"1843-44 - This Winter, with the exception of one good rain in November or early December, and a light rain in March, was almost rainless. No crops were raised in the Sacramento Valley, and nothing to speak of elsewhere."

From his study of the mission records, H. B. Lynch (Rainfall and Stream Flow in Southern California, 1931) found periods of generally deficient rainfall from 1792 to 1810 and 1822 to 1832. The season 1840-41 was also one of severe drought in southern California.

The effect of these early drought years was more severe on the then economy of the state than the deficient years 1928 to 1934. By this later period, irrigation enabled crops to be grown, particularly where ground water supplies, not subject to the immediate effects of such shortages in precipitation, were used. With the increasing use of reservoirs having sufficient capacity to equalize the runoff over series of years and of ground water draft, California's agriculture has become relatively well protected against the more severe effects of droughts.

Other Possible Sources of Water Supply

The records of water supply have been discussed on the basis that our present known and measured stream flow represents the original source of water that will be available for use. This is a sound conclusion insofar as prospective changes in precipitation or runoff are concerned. However, there are some opportunities for the salvage of sewage which are receiving increasing attention. Reclamation of sea water is also being extensively studied.

Salvage of Sewage

Municipal sewage is a material part of the total delivered municipal supplies. Recovery and reuse of sewage is practiced in some areas but its general extent is limited. A substantial part of the water used in the coastal area of southern California now escapes to the ocean. Increased facilities to enable sewage to be discharged into the ocean are being constructed and plans are being made to bring sewage from areas farther inland to such outlets. The technical problems of sewage reclamation can be met, but the public prejudice against the use of the reclaimed water for domestic purposes prevents its direct use. Sewage can be reclaimed for irrigation use. Irrigation use gener-

ally results in deep percolation to the ground water; fear of contamination has retarded use of sewage for irrigation where ground waters used for domestic purposes might be affected. Similar fears have prevented use of sewage for the irrigation of crops consumed directly. Large-scale use of reclaimed sewage for irrigation will require an extent of treatment approaching that required where sewage mingles with potable surface water supplies. As the costs for imported water increase, sewage treatment can compete economically as a source of water supply. Greater use of this source of supply may be required if construction of import systems should be delayed. Material changes in the public thinking will be required before this will occur.

Desalting Sea Water

In recent years there has been much interest and activity in desalting sea water. While this has been done successfully on a small scale where costs have not been a limiting factor, methods for large-scale production at competitive costs has not as yet been developed. Experimental work in recent years has resulted in reductions in cost, and eventually processes may be found which can produce usable water at a cost comparable with those which municipal use can afford to pay and competitive with the cost of some imported supplies. For areas near the ocean, reclaimed sea water may eventually become competitive with the delivered price of imported water. Farther inland the cost of treated sea water will include the cost of its conveyance to the area of its use. There is a sufficiently large use of water within the southern California coastal plain that a competitive source of reclaimed sea water would be a major item in the solution of the water problems of this area. Present prospects indicate that any process for treating sea water will remain more expensive than the cost of producing an equivalent product from sewage or the cost for imported water.

Weather Modification

There has also been much interest in efforts to increase the water supply by processes generally referred to as cloud seeding or rain making. The physics of increasing precipitation by such seeding and methods for its accomplishment have been worked out. There is still much argument over the amount of the effect of such practices. This uncertainty results mainly from the difficulty of finding situations where a rigid comparison can be made with the precipitation that would have occurred without treatment. In general, the results to date appear to support a conclusion that such procedures do not represent a means by which the precipitation over large areas can be materially changed. Arid areas can be expected to remain arid. The hope that precipitation may be increased by such operations should not affect plans for using the water supplies received under past conditions.

Climatic Cycles

Comment is frequently made that we are in a wet or a dry cycle. Rainfall varies in different single years and also in series of years. The occurrence of sequences of years having rainfall either above or below the mean, with generally dry periods alternating with wet periods, has encouraged the belief in weather cycles. Many analyses have been made to determine whether such cycles exist and in trying to relate the variations in climatic items to other factors.

Any consideration of weather cycles requires a definition of what they are, their characteristics, and how they can be recognized. There are many kinds

of cycles. To be useful for forecasting purposes, a cycle must have a sufficiently definite time period and amplitude so that its future variations can be predicted within the accuracy needed for the purpose for which the forecast is made. This test can be applied to various types of climatic variations.

A definite climatic cycle is illustrated by the variation of the time of sunrise or of tidal fluctuations at any selected location. The time of sunrise varies but it follows the same cycle year after year. The time of sunrise can be predicted definitely, as the cycle of its variation depends on known factors. The tidal cycle is shorter and more complex but is also known. Tidal predictions are computed in advance and check with the actual tides which occur.

Presumably precipitation is the result of definite physical causes and the individual factors which affect precipitation are subject to definite physical laws. These factors vary widely and rapidly within the area affecting precipitation at any one point. It is not possible to secure sufficiently complete observational material to enable precipitation to be forecast specifically as to time and amount at any particular location. All that has been attempted in predicting rainfall, for periods longer than a few days, has been to forecast the annual or seasonal total for a general area. Such forecasts have been made in terms of the total depth of precipitation in a given period or in terms of a percentage of the mean.

Efforts to derive climatic cycles have generally been based on comparison with other records which it was thought might be related to the climatic factor sought and which had cycles which could be derived from their available records. Direct continuous rainfall records which have been secured in California to date do not disclose any cycles of sufficient regularity to be used for forecasting precipitation in subsequent years. Eventually, rainfall cycles usable for forecasting, if they exist, may be derived when sufficiently long periods of record have become available.

As a substitute for direct records of precipitation, efforts have been made to find some item which is the result of rainfall which varies with the amount of the rainfall. The most widely used item of this type has been the annual rings of trees. Trees add to their diameter each year, with the annual growth ring sufficiently distinct so that it can be distinguished and measured. As growth requires moisture, the amount of the growth may be proportional to the moisture supply available up to the point at which the moisture needs of the tree are fully met. After this point is reached, growth becomes controlled by other factors.

The work that has been done on tree rings has resulted in the development of a technique of its own. Earlier results were not always consistent. Selection of trees for measurement to secure samples growing under critical moisture is now more carefully made. Methods of actual measurement of the thickness of each ring, the discovery of missing or double rings, and other details of these tree-ring analysis methods have become fairly well standardized. The observational part of tree-ring studies has been brought to a generally satisfactory status. These studies and the interpretations of their results have been accomplished largely through the work of A. E. Douglas of the University of Arizona and others working with him.

Tree-ring records for as long as 3,000 years have been secured from sequoia and redwood trees. Recently, bristle cone pines in the White Mountains of east central California have been found to be even older, one tree has rings indicating it to be 4,600 years old. Records for shorter lived varieties of trees have been developed for longer periods by what is called "cross-dating." A record from a tree covering one period is cross-dated to that of trees which grew during an earlier and partly overlapping period. Such earlier

specimens have been obtained from timbers preserved in the ruins of prehistoric buildings in the Southwest.

Conclusions by different investigators in this field are not in entire agreement in regard to the cycles which they may record. Cycles of different length have been claimed to be shown by these tree records. An interested investigator, not committed to any conclusions regarding any particular length of cycle which they may show, would probably conclude that these tree records do not show repetitional cycles of a uniformity of amplitude or time which can be used for forecasting purposes with assurance of success.

Another generally used factor which may cause climatic variations and which has been used in attempts to derive climatic cycles has been the sunspot numbers. Records of these are now available for several hundred years. The number of sunspots fluctuates between variable maxima and minima with variable time periods between adjacent highs and lows. The average length of the cycle has been about eleven years, with individual cycles varying from seven to fifteen years.

Much study has been given to the effect of sunspots on the climate of the earth. Here, again, variable conclusions have been reached. Some investigators claim to have found a relationship between sunspot cycles and precipitation, temperature, or even business or health cycles. None of such claims stands fully accepted as yet.

Forecasting the Water Supply

Precipitation in California depends mainly on the amount of evaporation from the Pacific Ocean and the air currents which bring such moisture over the land. If the storms of any season coming from the north over the Pacific Ocean do not swing far enough south before coming inland, the major storms of that season pass mainly to the north and California receives a below-average rainfall. When such storms swing farther south, California receives excess precipitation. The major general storms sweep the entire state, but heavy precipitation may be received either in the northern or in the southern part of the state without correspondingly heavy precipitation being received in the other portion.

Efforts have been made to find some factor which could be observed in advance which would indicate the character of precipitation to be expected in the following rainy season in California. Cycle projections have not shown reliability for this purpose. McEwen, at the Scripps Institute at La Jolla, based predictions on the temperature of the offshore ocean water. These forecasts showed a fairly high correlation with the actual precipitation for several years but further use of this method was less satisfactory.

From the results obtained by others and from his own studies in the field, it is the conclusion of the author that no one has, as yet, found a basis for long-range forecasting of precipitation in California which can be expected to give results essentially better than straight chance. Encouragement should be given to all well-considered studies in this field in the hope that more useful results may be secured. It is hoped that progress toward the end sought can be made, but it should be recognized that the final goal will be reached, if at all, only when the knowledge of all the factors involved and the extent of the observational data obtained is much greater than that now available.

Even if an adequate basis for forecasting the annual precipitation for several years in advance should be found, we will still, of necessity, have difficulty in evaluating its results. Climate within California is widely variable, not all of the state is ever all above or all below the mean in any year. This has made it very difficult to evaluate past forecasts, as some place could

usually be found which would verify the forecast even though such a place might be the exception rather than the rule. Winters generally recognized as wet or dry for major portions of the state occur, but there is difficulty in expressing the degree of wetness or dryness for use in making statistical analyses.

The studies that have been made on climatic variations have not as yet resulted in a demonstration of any definite trends toward either more moist or more dry conditions. While variations occur, the general average does not indicate any essential changes. There are indirect comparisons which indicate that no material change has occurred for time periods that are relatively long in terms of the span of human lives. Sequoia and bristle cone pine trees over 3,000 years old indicate that the climatic conditions have remained within the range of their adaptability for at least this length of time. Indirect records on enclosed lakes indicate some periods of apparently less inflow than that of the last hundred years but no continuous change is shown.

A reasonable forecast for the water supply of California for the next hundred years is that its average amount will be closely equal to that of the last hundred years and also that it will be similar to the amounts that have been measured during the last fifty years. The next hundred years should contain about the same differences between maximum and minimum years, about the same five-year periods of excess or deficiency and similar floods and droughts, but past experience does not support a conclusion that they will occur in the same sequence that was followed in the last hundred years. We cannot count on having greater water supplies during the next hundred years than in the last century; neither should we fear that there will be any material reduction or more severe droughts in the next hundred years.

Full use of a stream includes its regulation by storage not only to equalize the supply and demand between the different months of the same year but to equalize also the varying supply of series of years. Any knowledge of the runoff expectancy for one or more years in advance would enable more effective use to be made of such storage. It is now usual to retain some emergency supply in reservoirs to meet possible extreme conditions if they should arise. If the runoff of ensuing years could be known, such carry-over could be reduced and the total use of storage increased. The type of annual crops to be planted, as well as the area to be irrigated, could be adjusted to the water supply to be available.

Annual Snow Surveys

There is one method of forecasting runoff in advance of its occurrence in single years that has become well established and which is giving dependable and useful results. This is the so-called snow surveys. Its usefulness arises from the fact that on the higher drainage areas which provide the main part of the summer runoff, the snow falls from about December 1 to April 1 but its melting and runoff occurs mainly from April 15 to July 1. By measuring the water content of the accumulated snow prior to its melting, estimates can be made of the runoff it will produce. The water content has been obtained by actual measurements of cores of borings through the snow taken at selected typical courses on the drainage area. The correlation between the amount of snow and the resulting runoff is developed from experience on each drainage area; the relationship found in past years being used to predict the expectancy of each later year. While this procedure is empirical, it has been found to be useful. On Sierra Nevada drainage areas where records have been secured for ten or more years, predictions within an accuracy of 20 percent are usual and in many years the forecasts may be within 10 percent. While preliminary fore-

casts can be made as the snow accumulates during the winter, the final estimates are not made until about April 1. This is early enough to have value in planning the operations for the succeeding months for power, irrigation, and other water uses. In years of indicated deficient water supplies, power systems can plan their steam generation in advance and irrigation systems can conserve their limited water supply by reducing the areas of annual crops.

Forecasts based on snow surveys differ fundamentally from predictions based on cycles or observations of other climatic elements. Snow surveys are not in reality true forecasts, as they represent a measurement of precipitation that has already occurred. The uncertain elements in snow surveying are limited to the accuracy of the sampling of the snow on the entire drainage area and to the variations in temperature and in additional precipitation during the melting period. Estimates of runoff based on snow surveys are usually expressed in terms of the total runoff to be expected during the period of snow melting.

Ground Water

A source of water supply which it is more difficult to inventory is the ground water. Use of ground water in California is extensive for irrigation, domestic, municipal, and industrial purposes. California is fortunate in having extensive basins filled to great depths with porous material which has been eroded from the adjacent higher drainage areas. The larger part of these alluvial fills are sufficiently porous so that good yields from wells can be secured. Ground water in these basins occurs within economic pumping lifts from the ground surface. Draft on the ground water began relatively early in the irrigation development of the state and has been a major source of its supply for the last fifty years.

While engineering studies have determined the extent and safe yield of many ground water supplies in the state, no inventory of the total supply of the state has been made. Such an inventory would overlap the summation of surface runoff which has been presented, as much of the ground water has its source in the percolation from stream channels below the points at which the stream flow is measured. Ground water recharge also occurs in some areas from the direct penetration of rainfall on overlying areas.

The U.S. Census of Irrigation for 1939 illustrates the extent to which ground water was used in California in that year. An area of 1,519,000 acres was found to be irrigated entirely with water secured from wells; this represented about 30 percent of the total area irrigated in California and about 60 percent of the total area irrigated from wells in the United States. Of this area only about 7,500 acres were supplied entirely or partly by flowing wells. This illustrates the extent to which draft on the ground water in areas formerly artesian has reduced the pressure so that pumping is required. The artesian areas were developed first, and from the early development of the state until about 1900 the area supplied by artesian flow probably exceeded that served by mechanical pumping. In addition to the 1,519,000 acres served entirely from wells in 1939, 1,008,000 acres of land receiving water from streams secured supplemental water from wells.

The 1939 census did not attempt to secure the amount of water pumped for the irrigation of the lands served from ground water supplies. If the average draft for the lands wholly served by wells was 2.5 acre-feet per acre and for the lands partly served 1.5 acre-feet per acre, the indicated total annual irrigation draft from wells would have been about 5,000,000 acre-feet. With allowance for ground water draft for other purposes, the total annual draft on ground water in California in 1939 may have been six to seven million acre-feet.

In Bulletin 3 it was estimated that more than half the water then consumptively used in California came from underground sources. In Bulletin 2 of the same Board it was estimated that the 1953 consumptive use of water in California was 14,810,000 acre-feet. On this basis the total consumptive use of ground water may be about 8,000,000 acre-feet per year. In Bulletin 3 it was also estimated that the 1955 draft on ground water in excess of the safe annual yield was about 4,000,000 acre-feet. These results indicate that the safe annual yield of ground water in California may be on the order of 4,000,000 to 5,000,000 acre-feet. As pointed out in Bulletin 3, much more study will be necessary to evaluate reasonably accurately the capability of the ground water resources of the state.

The present draft on ground water in the state does not represent the available supply or safe yield in all areas. In some cases the available supply is not yet fully developed; unfortunately, in many areas the present draft exceeds the safe yield. Projects to supplement some present ground water supplies are now under construction or being planned. Relatively, the ground water supplies are now much more fully utilized than the surface supplies. The Central Valley Project had for its main purpose the conveyance of a supplemental water supply to areas of ground water overdraft on the east side of the southern part of the San Joaquin Valley. A main function of either federal or state projects to convey water into the upper west side of the San Joaquin Valley will also be the replacement of present ground water overdraft.

Intrusion of sea water into the adjacent ground water has occurred in some, and is threatened in other, areas where the ground water draft exceeds the recharge. Permanent relief requires overcoming the overdraft and restoring the seaward ground water slope. Providing water to meet the overdraft is a part of the general water supply problems of each of the affected areas. In some cases such water supplies can be provided by additional development of local sources; in other areas importation of distant supplies will be required.

Prior to settlement of the coastal areas, the ground water adjacent to the seashore was generally under pressure. As previously discussed, the artesian pressures in some cases were sufficient to supply domestic use without pumping. This is the condition to be expected where recharge water enters a porous fill underlying clay strata at an elevation above that of its outlet. The original ground waters built up pressures sufficient to provide outlets for the inflow. Such outlets were movement seaward to wherever the porous strata may have outcropped in the ocean or upward leakage through the confining clays. Where outlets in the ocean existed, the reversal of the ground water gradient, when the inland ground water is lowered below sea level, furnishes a channel and a grade for sea water to move inland. Each area where sea water intrusion may occur represents a separate problem requiring consideration of the local conditions for its solution.

Quality of Water

In addition to the problems relating to the quantity of water, in some areas water that may be available may not be suitable in quality for use for irrigation or other purposes. Such questions regarding chemical quality of water occur more often in relation to ground water than to surface streams. These questions are important in areas where waters of poor quality occur. Fortunately, waters of poor quality are unusual and nearly all of the available water supplies in California are suitable for general uses. Some of the larger

streams draining higher areas of generally granitic character have waters of unusual purity.

All waters contain some solubles. Use for irrigation and reuse of the waters by recovery of percolation tend to concentrate the solubles in the residual ground waters. For permanent maintenance of the quality of the supply it is necessary that some water be wasted in order to maintain a favorable salt balance. The amount of salt being brought into some areas in the water which is used may exceed the amount being removed by the outflowing wastes. Under such conditions salt accumulations are occurring which may eventually result in increasing the salt content of the local ground water supplies beyond the limit of tolerance or in rendering crop lands too alkaline for cultivation.

The amount of salt which may occur in waters without the water becoming unsuited for use varies with the character of the particular elements involved. Usual analyses report the carbonate and bicarbonate, chloride, sulphate, calcium, magnesium, and sodium either in parts per million or in milligram equivalents per liter. Total salts without segregation may be measured by means of the specific electrical conductance. Boron is a special element that may be harmful in very small amounts. Waters high in sodium are more harmful than those in which the salts are mainly calcium or magnesium. Less chloride can be tolerated than sulphate.

The limits of tolerance for the different solubles and for the total amount vary for different uses of water. For irrigation such tolerances vary with individual crops and conditions of use. Some salt-tolerant crops can be successfully grown with water which would be unusable on more sensitive crops. Waters with higher solubles can be used on lands having good drainage if surplus waters are applied for soil leaching.

The qualitative limitations of irrigation water, for the above reason, cannot be rigidly defined. Waters for irrigation can be divided into classes varying from excellent to injurious and limiting amounts of each factor defined for the different classes. A classification of this type, widely used in California, is that of L. D. Doneen of the University of California at Davis. This has been used by the State Department of Water Resources and is summarized in its Bulletin 1.

Waters from the Sierra, with relatively few exceptions, are good to excellent in quality. Ground waters in valley areas recharged from Sierra sources are similarly of good quality. The waters derived from the Coast Range have absorbed larger amounts of detrimental elements and in some areas have concentrations which may be injurious. Analyses and experienced advice are needed before the safety of the use of such waters can be determined. Some lending agencies now require analyses of the water to be used as a part of the information on which their actions on loans are based.

Quality of water is an important element in areas that may be affected by sea water. The delta of the Sacramento and the San Joaquin rivers is an example of the effect of tidal flows on surface waters. Unless the inflow to the delta from its various fresh-water surface tributaries is sufficient to repel the tide waters flowing into the delta from San Francisco Bay at times of high tide, the waters in the channels of portions of the delta may become sufficiently salty to be detrimental if used for irrigation. As the salts in sea water are mainly the common salt (sodium chloride), limits of tolerance have been defined in terms of the chloride. A chloride content of 100 parts per 100,000 has usually been regarded as the dividing point between usable and dangerous water for irrigation. For domestic and industrial use the usual limit set has been 25 parts of chloride per 100,000 parts of water.

Sea water may contaminate ground waters near the ocean. The coastal areas

in which ground water supplies are available had sufficient ground water elevations prior to development of these supplies so that the ground water slope and flow was toward the ocean. In some of these coastal areas the ground water was artesian and under sufficient pressure so that flowing wells could be used for domestic supplies in two-story buildings. Use has depleted these ground water supplies so that artesian flow is no longer available or the wells may flow only during short winter periods of reduced draft. In some cases the ground water has been lowered below sea level so that the pressure gradient is now inland from the ocean to these depleted areas. Some salt-water contamination has occurred. These situations are being closely watched and studied. The use of some wells has been discontinued. The final remedy is to limit the draft on the ground water so that depletion below sea level is avoided. To do this and still maintain existing use requires securing substitute water supplies. The Metropolitan Water District of southern California is providing such substitute supplies in some of the areas it serves, both by artificial additions to the ground water by recharge through spreading and by reduction in draft by direct delivery from the district. Pollution by sea water, if it occurs, is difficult to remove and may contaminate the supplies for long periods. Prevention of its occurrence is the necessary and practical procedure in areas subject to this danger.

Land Resources of California

Land resources are closely related to water resources. The character of the land controls the runoff that will occur from the precipitation. To make the development of the water resources feasible, lands suited to municipal, industrial, and agricultural uses are required. In humid areas the land resources are relatively more important than the water resources; in arid areas the reverse is generally true. In California, which varies from humid to very arid in its different parts, water resources are the limiting factor in the ultimate development that may be achieved. California has adequate areas of suitable land for the use of the population it may eventually have and has adequate water for the domestic requirements of such a population. California also probably has adequate agricultural land to support its future population if water can be made available for its productive use. While there is a reasonable balance between the over-all water supply and the available irrigable area, in many parts of the state there is more suitable land than the water resources can supply, at least within any standards of feasibility that are now foreseeable.

While land is a fixed resource and can be readily measured, there is no single standard generally accepted for its classification. Lands vary widely in their character and opinions regarding the usefulness of some types of land still differ. Lands can be classified definitely as to their physical properties, but individual opinions naturally vary on the economics of their usefulness. The range of these differences is being reduced as greater detail knowledge and experience is acquired. Enough is now known regarding lands so that no project should go very wrong in its estimate of the potentialities of its included area. In some cases the available knowledge in this field has been in advance of the willingness to accept the results of this knowledge and we may continue to see poor lands included in projects where such knowledge is not heeded.

Soil surveys made by state and federal agencies are making detail information available on the soils of the larger part of the agricultural lands of the state. Eventually these surveys will represent an inventory of the total area usable for agricultural purposes. To date such detail is incomplete. Reports have been made on the total land resources of the state but these, of necessity, have rested on reconnaissance types of information for many areas.

The total land resources of the state, as well as its water resources, were surveyed in 1912 for the then State Conservation Commission by the U.S. Department of Agriculture (Office of Experiment Station Bulletin 254). The total area found to be suitable for agriculture was 21,865,000 acres. This report was based on a reconnaissance type land classification.

In Bulletin 6 of the State Division of Engineering and Irrigation, prepared in 1922, the agricultural areas of 16 divisions of the state were estimated. These results are shown in Table III. These results were used in preparing Bulletin 25 of the State Division of Water Resources in 1930. Bulletin 25 was the report to the Legislature of the then State Water Plan which related principally to the initial plan proposed for the Central Valley Project.

TABLE III
AGRICULTURAL AREAS IN CALIFORNIA

Location of Area	Agricultural Area Acres
Los Angeles area, Ventura to Redlands	1,310,000
San Diego area, Mexican boundary to San Jacinto and Yucaipa	984,000
Imperial, Coachella, and Palo Verde valleys	1,299,000
Antelope Valley and Mojave River areas	1,107,000
Inyo-Kern, Owens, and Mono valleys	657,000
Sierra foothills and rolling plains east and south of San Joaquin Valley floor	1,800,000
San Joaquin Valley floor	5,468,000
Western slope of southern San Joaquin Valley	971,000
Santa Barbara, Santa Maria, and San Luis Obispo area	410,000
Salinas and contiguous valleys	296,000
Santa Clara and adjacent valley areas	530,000
Delta lands of San Joaquin and Sacramento valleys	453,000
Sacramento Valley floor	2,694,000
Sierra foothills and rolling plains east and west of Sacramento Valley floor	2,305,000
North coast area	624,000
Northeastern mountain-valley and plateau areas	1,598,000
TOTAL	22,506,000

The most recent results of the state relating to lands in California are those in Bulletin 2 entitled Water Utilization and Requirements of California (1955). The total area of lands adapted to agricultural use is not separately stated. However, the ultimate water service areas are given as 19,050,000 acres of irrigable lands and 3,411,000 acres of urban and suburban area, a total ultimate water-using area of 22,461,000 acres. These results represent the ultimate areas estimated to be suitable for use for irrigation or urban purposes. Numerically, these are similar to the total area found in the 1912 and 1923 surveys for the total area of agricultural land in the state. This agreement is the result of the state water plan in Bulletin 3 being based on meeting the water requirements for the complete development of the state.

While the later land classifications have been based on much more extensive field surveys and detailed standards of classification, the overall results of the 1912 and 1955 reports are in relatively close agreement. This is to be expected, as the physical characteristics of these lands have not changed and experience has not found means of utilizing material areas of land considered to be nonagricultural in the earlier work.

Areas Ultimately Irrigable

In the report prepared for the State Conservation Commission in 1912 by the U.S. Department of Agriculture, the areas that might ultimately be irrigated were also estimated. These estimates for the type of projects then being considered were based primarily on the use of the waters of each stream on lands in its vicinity. The general results are shown in Table IV.

TABLE IV
SUMMARY OF AGRICULTURAL LANDS IN CALIFORNIA AS ESTIMATED IN 1912

	Acres			
Division of State	Agricultural Areas in Irrigation Zones	Areas Irrigated in 1912	Total Areas It Is Estimated May Ultimately Be Irrigated	Percent of Total Estimated as Ultimately Irrigable
Northern California	6,200,200	487,805	3,450,000	56
Central California	9,665,000	1,959,355	4,300,000	44
Southern California	6,000,000	745,486	1,949,600	33
TOTAL	21,865,200	3,192,646	9,699,600	44
Selected Areas				
Sacramento Valley	3,449,000	123,500	2,500,000	72
San Joaquin Valley	7,576,000	1,728,975	3,850,000	51
Southern California Coastal	2,191,575	350,397	1,060,100	48
Colorado Desert	1,550,750	279,600	766,500	49
Mohave Desert	2,328,000	15,489	113,000	5

In Bulletin 25, in 1930, it was estimated the net water service areas which ultimately will require a water supply, if they are developed, was 16,673,000 acres. The water requirements of these lands were used in estimating the ultimate water supply that would be needed. In Bulletin 2, in 1955, the approximate total of the probable ultimate areas of irrigated lands was 19,050,000 acres.

The large increase in the ultimate irrigated areas between the 1912 results and those in 1923 continuing to 1955 reflects the changing standards in project thinking, particularly the distances water would be transported from areas of supply to areas of use. It also reflects the more lenient economic standards now applicable to irrigation development.

Ultimate Water Requirements

Past reports have estimated the development of the water supply of the state which may ultimately be reached. Comparison of such results requires a consideration of the meaning of ultimate.

One meaning found in a 1908 edition of Webster's Imperial Dictionary is "being that to which all the rest is directed or which cannot be gone beyond." Usual shorter meanings are final and complete. Ultimate development in an area having a surplus of water would be reached when all suitable lands and possible populations were fully served. In an arid area the ultimate would be reached when all available water was fully used.

The above definitions are based on physical resources. An area may have available waters and lands but the value of the use of the water may be less than the cost of its development. Estimates of ultimate where consideration is given to economic feasibility will vary as the results of the optimism or pessimism of the estimator. They will also vary with the changes in economic standards that may occur.

Any area which has reached the ultimate development of its water supply has no place in which it can expand its water economy. Such a condition is unknown, as yet, in this country. The United States has only recently emerged from its pioneering stage and its entire philosophy is still based on expansion. If California ever actually reaches a stage in its water development where no further expansion can be made, the initiative that produced such a development will be lost and stagnation will occur. It is said that an economy never remains in balance; it either goes ahead or it goes backward. On this basis, ultimate is a condition to be avoided rather than one to be sought.

While planning and programming of development is essential to orderly progress, care is required to avoid so much emphasis on some future ideal that projects now needed are handicapped in their present construction. A balance between future ideals and present necessities is required if orderly progress is to be made. Two-lane highways were built before traffic required four lanes; without the two-lane roads, traffic to support four-lane construction would not have developed at the rate we have experienced. Similarly, an irrigation project built today may not conform to some ideal for the future, but it may pay its costs and supply support which can finance larger later projects. Replacements for some reservoirs which have been built long enough to have repaid their costs are now being considered. This emphasizes the value of the early construction of the original storage rather than reflecting on the judgment of those responsible for the original plan.

In Bulletin 25 of the State Division of Water Resources on the 1930 state water plan, the gross water service areas of the state were estimated to be 22,843,000 acres, of which it was estimated that a net area of 16,673,000 acres would eventually require the gross annual use of 46,816,000 acre-feet of water.

In Bulletin 3 the State Department of Water Resources has estimated the water requirement of the state in 1950 and for ultimate development. The results for the different types of use are shown in Table V.

TABLE V
ESTIMATED PRESENT AND ULTIMATE WATER REQUIREMENTS OF CALIFORNIA

Results of State Department of Water Resources in Bulletin 3

Use	Acre-feet Per Year		
	Requirements in 1950	Estimated Probable Ultimate Requirements	Present in Percent of Ultimate
Irrigation	19,044,000	41,106,000	46
Urban, Suburban, and Industrial	1,656,000	8,301,000	20
Miscellaneous	333,000	1,721,000	19
TOTAL	21,033,000	51,128,000	41

Table V indicates that the development in 1950 represented about 40 percent of the estimated ultimate requirement. To reach this ultimate use, California will have to increase the use reached in its first century of development by one and one-half times.

Table V shows that the major need for water, both present and ultimate, is for irrigation; about 90 percent of the present use and 80 percent of the ultimate requirements are for irrigation.

The extent of the present use of water in relation to the ultimate use varies in the different parts of the state. This is shown in Table VI, also taken from Bulletin 3. The Central Valley and the Colorado Desert areas are using about one-half of their estimated ultimate need. For the Central Valley this is the result of suitable lands adjacent to adequate water supplies; for the Colorado Desert it is the result of the use of Colorado River water by the Imperial and the Palo Verde irrigation districts. For the north coastal area use has been limited by lack of demand; for the Lahontan area it has been limited by lack of local water supplies.

TABLE VI
DISTRIBUTION OF ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL WATER REQUIREMENTS IN CALIFORNIA

Results of State Department of Water Resources in Bulletin 3

Hydrographic Area	Requirements in 1950 Acre-feet	Estimated Probable Ultimate Requirement Acre-feet	Present in Percent of Ultimate	Percent of Total Use	
				Present	Ultimate
North Coastal	513,000	2,064,000	25	2.5	4.0
San Francisco Bay	710,000	3,512,000	20	3.4	6.9
Central Coastal	630,000	2,246,000	28	3.0	4.4
South Coastal	1,907,000	5,552,000	34	9.1	10.9
Sacramento River Basin	3,819,000	7,427,000	51	18.1	14.5
San Joaquin—Tulare Lake Basin	9,373,000	16,305,000	56	44.5	31.9
Operation of Salinity Control Barrier	0	876,000			1.7
Lahontan	741,000	6,736,000	11	3.5	13.2
Colorado Desert	3,340,000	6,410,000	52	15.9	12.5
TOTAL	21,033,000	51,128,000	41	100	100

At present about 63 percent of the total use of water is in the Central Valley, 16 percent in the Colorado Desert, 9 percent in the south coastal area, and the remaining 12 percent in the other areas of the state.

Comparison of Water Supply and Demand

The results that have been presented on the total water supply of the state and the total predicted demand for its future use show a substantial excess of the supply over the demand. On this basis alone, California can meet all of its future demands for the use of water.

This overall excess of water supply is only one of the elements needed to enable California to meet its future demands. It is the primary requirement, as the demands cannot be met unless the water supply is present in the state. Such a general comparison, however, omits the economic feasibility of regulating the variable runoff and delivering it to the areas of use. The results in Bulletin 3 give only limited consideration to the costs of securing water to meet the demands of the areas of need. How far California may go in meeting its ultimate water demands will depend on the costs which the last increments of such development can afford to pay to meet their demands. This same standard applies to the projects proposed for present development and uncertainty regarding the extent their cost could be met has delayed progress to date.

It will require much more than a general statement that California has enough water to meet its ultimate demands to solve the many problems that will have to be met before water can be supplied to all areas of demand. Recognition of these problems and active efforts toward their solution is required before substantial progress toward their solution can be expected.

In succeeding chapters, the accomplishments to date are discussed. An understanding of what has been done is essential to sound planning for the future.

§ 621. In actions respecting "Mining Claims," proof shall be admitted of the customs, usages, or regulations established and in force at the bar, or diggings, embracing such claim; and such customs, usages, or regulations, when not in conflict with the Constitution and Laws of this State, shall govern the decision of the action. Proof respecting "Mining Claims."

Chap. 95.

AN ACT *adopting the Common Law.*

Passed April 13, 1850.

The People of the State of California, represented in Senate and Assembly, do enact as follows:

The Common Law of England, so far as it is not repugnant to or inconsistent with the Constitution of the United States, or the Constitution or laws of the State of California, shall be the rule of decision in all the Courts of this State. Common law of England to rule decisions of courts.

CHAPTER III

Water Rights and Water Laws

To understand the development of the waters of the state for their various uses, it is also essential to have a knowledge of the basis of titles to their use. As in many other fields, California has been a leader in the development of the principles of such titles. Mining development, on an extensive scale, occurred earlier in California than in the other parts of the West, and California miners carried the customs developed here to the other states. In later years, when California confirmed the system of riparian rights in surface streams, the other states had proceeded far enough in their uses of water to see the disadvantages of this system in arid areas and to avoid California's mistake in this regard.

California can claim the dubious honor of having had more litigation over water than any other state. This claim has not been disputed; it is one item where being the "biggest" does not reflect credit on California. A large part of this litigation was the result of the natural competition to secure shares in a limited but essential natural resource. A larger part was also the inevitable result of attempting to develop the state under two systems of title to water that were inherently in conflict. California's recognition of riparian rights in surface streams created an unavoidable conflict with use under appropriation

rights for which a basis of compromise was not found until there had been forty years of litigation, extending from the decision in Lux vs. Haggin to the passage of the constitutional amendment of 1928.

Water rights were not an issue prior to the discovery of gold in 1848. What later became the pueblo rights of San Diego and Los Angeles to the waters of the San Diego and the Los Angeles rivers, respectively, had been created, although they were not recognized by legal action until after statehood. Water for other purposes was useful mainly as the place where beavers could be trapped, as a controlling element in the location of camps, or as a hardship in the case of floods; for all of these uses no individual titles in the water itself were needed.

Adequate discussion of water rights in California on a legal basis requires lengthy treatment. A legal text entitled Water Rights in the Western States by Samuel C. Wiel, published in 1912, consisted of two thick volumes. Much of this treatise related to the then conflicting status of riparian and appropriation rights. In 1956 the state published The California Law of Water Rights by Wells A. Hutchins. This consists of one volume of about 500 pages. The discussion attempted here seeks to outline the history of the development of the principles used to define water rights in California and to describe the experience of the state with its development under these principles. The purpose is to treat water rights from the point of view of desirable public policy rather than technical legal procedures.

Early Mining Customs

The earliest extensive use of water in California was in mining. Diversions from streams to an extent that resulted in demands in excess of the supply and required a system of titles for the rights to use water did not occur until the mining for gold resulted in water shortages during periods of low stream flow.

When California became a part of the United States, there were no statutes or administrative agencies by means of which title could be secured to either land or water. All lands, except those in Spanish or Mexican land grants, were in the ownership of the federal government. These land grants were mainly in the valleys. Laws and procedures for acquiring federal lands had not been established. The only local government was military, having for its purpose the protection of the few settlers from the Indians. The miners, even if they had desired to do so, had no process by which they could have secured title to their mining claims from the federal government. All miners were trespassers on the public domain.

This condition was recognized by the early miners. They did not concern themselves about trespassing on the public land and the local military forces made no effort to prevent their operations there. However, the influx of miners soon made it necessary for them to have some system of titles as between themselves to both lands and waters. To their credit, the miners by majority action developed such systems by an orderly process of establishing rules applicable to each mining district. These rules were generally similar in the different districts but had some local variations.

For the mining claims themselves these rules included a limit on the area that could be held and a requirement of diligence in working the claim in order to hold title. These rules prevented a monopoly of the gold-bearing areas or the holding of claims without working them. To recognize the reward due to the discoverer of gold in any area, he was entitled to select and stake his claim on its discovery. To show the location of the claim, it had to be marked on the ground by specified stakes and notices. To preserve a record of the claim, a copy of the posted notice had to be recorded.

When the need for a system of title to the use of water arose, it was natural

for the miners to adopt the same principles they were using for their mining ground to cover rights to their use of water. They recognized that the first to make use of water should have a preference over later users, but they limited all use to the amount of water needed for the purposes for which it was used. They also required diligence in the construction of works and the use of water as the basis for acquiring and maintaining a right to use.

These early rules were worked out, adopted, and enforced by the miners in each area. Their adoption usually occurred at local meetings called for that purpose. The rules in different areas naturally varied in details but had the same general object. These same principles are still the basis of present mining laws on the public domain and of appropriation rights to the use of water. The soundness of the principles adopted by these early miners is shown by their retention and use under the more complex conditions of the later development of the state.

The effectiveness of the appropriation system of titles to the use of water is the result of its checks and balances. An unlimited recognition of the priority of right would enable water to be held in excess of the needs of the appropriator; this is offset and prevented by the requirements for beneficial use and diligence. Priority of right cannot be used to hold water speculatively without use. Diligence must be used in the completion of the works required for the use of water and in the putting of the water to actual use. Even after an appropriation right has been acquired, it may be lost by abandonment or forfeited by nonuse.

The appropriation system of title to the use of water differs materially from the riparian rights recognized in the English common law. Some of the early miners were acquainted with the principles of water rights used in England. The riparian system of water rights recognizes a preference in the use of water to those owning lands along the stream. This preference is a part of the riparian land and is not affected by the time at which water may be used. The riparian system was not adapted to the conditions in the early mining areas and the miners developed a system better suited to their needs.

Early Legislation

The customs of the mining camps were recognized by the California Legislature in April 1851, within a few months after the state had been admitted to the Union. This legislation is as follows:

"Proof Respecting Mining Claims

"In actions respecting Mining Claims, proof shall be admitted of the customs, usages, or regulations established in force at the bar, or diggings, embracing such claim; and such customs, usages or regulations, when not in conflict with the Constitution and Laws of this State, shall govern the decision of the action."

Various matters relating to water received the attention of the California Legislature in its earlier sessions. These covered navigation, fish, surveys for irrigation systems, and provisions for county officers to supervise irrigation development.

The first Legislature in California in 1850 passed an act declaring a list of streams to be navigable and making it unlawful to obstruct them by bridges or dams. The earliest California legislation relating to fish was in 1852. This was amended in 1854. Weirs, stop-nets, or other means of obstructing the salmon run were made public nuisances. No one except the Indians could fish with seines or nets in July, August, November, and December.

The need for some supervision of the use of water was recognized by the Legislature as early as 1854. Provision was made for a board of three commissioners and an overseer in nine designated counties. On petition of the majority of voters in any township, an election was to be held for the selection of a board and an overseer. Their duties were to supervise the construction and operation of irrigation systems. They were empowered to call on every able-bodied citizen from 16 to 50 years of age who was using the ditch to do up to twelve days' work per year on it.

In 1857 a special board of three commissioners was created for San Bernardino County having authority to regulate water courses. Overseers could be appointed to lay out ditches, apportion water on an acreage basis, and to set up schedules of delivery and of work on the ditch. On such required ditch work the eight-hour day was to be used; supplying two horses counted as one man and a plow, wagon, or scraper as half a man. The overseer received $2.00 per day for his services. Costs were to be collected as taxes proportioned on the water used. In 1864 the Legislature made the board elective. Such a board was active during these early years in water matters in this county.

An 1874 act providing for the promotion of irrigation in Los Angeles County included a provision that artesian wells must be capped when not in use. Water was declared to be the property of the people for the "greatest possible good upon the greatest number." This appears to be the first California legislation relating to ground water.

Federal Act of 1866

While the miners worked out systems of title to their mines and the waters used in mining as between themselves, they did not have any land titles that were good as against the federal government which was the actual owner of the public domain. This condition was a matter of increasing concern as investments in the mining works reached larger proportions. It became serious when proposals were made in Congress, after the conclusion of the Civil War, that the federal government should assert its title to the mineral lands, dispossess the trespassing miners, and operate the mines for the profit of the government. This aroused the western interests and they secured the passage by Congress of the Act of 1866 by which the federal government recognized the titles acquired in its lands where the requirements of the local laws and customs had been followed. This gave legal recognition to the miners' titles and made proof of compliance with local laws and customs the controlling factor in the establishment of such titles. The Act of 1866 with the amendments of 1870 is still in effect for unreserved public lands for purposes other than power. It is not used now, as it has been superseded--even though it has not been repealed--by later statutes providing other methods of acquiring such rights of way under more definite procedure.

The Act of 1866 has also served as the basis for the acquirement of rights to the use of water by local or state procedure. While the title to public land was in the federal government, to date title to the use of water has generally been left to acquirement in accordance with the laws of the individual western states.

Extralegal Actions

While the miners' customs were generally well enforced by local action, all matters relating to titles to water were not as orderly as the previous comments may imply. Direct action was not unknown. Such occurrences appear to

have been more frequent where water was used for irrigation than they were in the mining areas.

An example of well-organized "extralegal" action in solving water rights problems is represented by the removal of the Cache Creek Dam in 1868. The Clear Lake Water Company was authorized by the Legislature in 1866 to build a lock in Cache Creek near the outlet of Clear Lake. This franchise was for thirty years and permitted operation of the lock if it did not lower the lake more than one foot in July and August below its usual depth in these months and if it did not raise the lake above the point where it usually stands. A dam was constructed at the outlet of the lake under the authorization of this act. Water reached the level of Main Street in Lakeport in the winter, and the owners around the lake claimed the water was higher at extreme low water with the dam than it had been previously at extreme high water. Farms adjacent to the lake were overflowed. Houses had to be vacated and claims were made that malaria had become generally prevalent.

The dam was two miles below the outlet of Clear Lake. The company contended they had removed snags from the outlet channel and improved its discharge. They also claimed that the high water was the result of two successive years of large inflow and not from the effect of the dam. The natural outlet of the lake is restricted and the elevation of the lake rises at times of large inflow until the excess supply has time to be discharged through the outlet.

The company won the litigation brought by the landowners to compel the removal of the dam. The judge in the final trial indicated that the landowners would have to seek relief in a higher court than his. Accepting this as a suggestion for direct action, about 300 local residents met on November 15, 1868, and organized themselves into a voluntary company, captured the sheriff and superintendent of the dam and the mills which it operated, burned the flour, saw and planing mills, and destroyed the dam. The company sued the county for the damages caused to it by this action; this claim was settled by the county in 1871 for $20,000. The reports of the action of the group destroying the dam include accounts of its organization, placing pickets to intercept anyone seeking outside relief, and the general military type of the organization. While it was referred to in some accounts as "riot action," it was not the usual impulsive type of action but a deliberate and planned undertaking.

Statutes of 1872

In 1872 the Legislature defined the general principles of the appropriation system as developed by the miners in thirteen brief sections which became Sections 1410 to 1422 of the Civil Code. These sections represented practically the entire statutes on this subject for some forty years. They were largely superseded by the Water Commission Act in 1914 which changed materially the form of procedure for the appropriation of water but did not alter the fundamental principles.

The 1872 statute is a very good statement of the basic elements of the appropriation system of title to the use of water. This was done in one page of statutes. It is worthy of being quoted in full even in a volume directed principally to a less technical form of presentation. Present statutes covering the same rights and the procedures relating to them cover over forty pages of the Water Code. This illustrates the greater statutory detail required for a centralized system of state administration of water rights and the necessity for being more explicit in all details under our present complex developments. The 1872 statutes are as follows:

"Sec. 1410. The right to use of running water flowing in a river or stream or down a canyon or ravine may be acquired by appropriation.

"Sec. 1411. The appropriation must be for some useful or beneficial purpose, and when the appropriator or his successor in interest ceases to use it for such a purpose, the right ceases.

"Sec. 1412. The person entitled to the use may change the place of diversion, if others are not injured by such change, and may extend the ditch, flume, pipe, or aqueduct by which the diversion is made to places beyond that where the first uses were made.

"Sec. 1413. The water appropriated may be turned into the channel of another stream and mingled with its water, and then reclaimed; but in reclaiming it the water already appropriated by another must not be diminished.

"Sec. 1414. As between appropriators, the one first in time is first in right.

"Sec. 1415. A person desiring to appropriate water must post a notice, in writing, in a conspicuous place at the point of intended diversion, stating therein:

1. That he claims the water there flowing to the extent of (giving the number) inches, measured under a four-inch pressure;
2. The purpose for which he claims it, and the place of intended use;
3. The means by which he intends to divert it, and the size of the flume, ditch, pipe, or aqueduct in which he intends to divert it.

A copy of the notice must, within ten days after it is posted, be recorded in the office of the recorder of the county in which it is posted.

"Sec. 1416. Within sixty days after the notice is posted, the claimant must commence the excavation or construction of the works in which he intends to divert the water, and must prosecute the work diligently and uninterruptedly to completion, unless temporarily interrupted by snow or rain.

"Sec. 1417. By 'completion' is meant conducting the waters to the place of intended use.

"Sec. 1418. By a compliance with the above rules the claimant's right to the use of water relates back to the time the notice was posted.

"Sec. 1419. A failure to comply with such rules deprives the claimants of the first right to the use of the waters as against a subsequent claimant who complies therewith.

"Sec. 1420. Persons who have heretofore claimed the right to water, and who have not constructed works in which to divert it, and who have not diverted nor applied it to some useful purpose, must, after this title takes effect, and within twenty days thereafter, proceed as in this title provided, or their right ceases.

"Sec. 1421. The recorder of each county must keep a book, in which he must record the notices provided for in this title.

"Sec. 1422. The rights of riparian proprietors are not affected by the provisions of this title."

Riparian Rights

The state Legislature in April 1850 passed a statute providing that "The common law of England, so far as it is not repugnant to or inconsistent with the Constitution of the United States, or the Constitution or laws of the State, is the rule of decision in all the courts in this State." This provision was adopted prior to the admission of the state but was continued in effect by the

provision of the Constitution recognizing statutes in effect at the time of the admission.

The English common law on waters was developed under humid conditions. In England, streams were useful mainly as a source of domestic and stock water and to generate power for grist mills. For such conditions it was natural to recognize the advantage of the position of lands along a stream in securing use of the waters of the stream. From this developed the riparian system of title to the use of water in which the flow of a stream is the joint property of its riparian owners. Rights went with the riparian land without advantages resulting from priority of use. Use had to be reasonable as between different riparian owners as a group, but all riparian owners had preference over users on nonriparian land.

The approval of the mining laws and customs by the Legislature in 1851 and the general adoption of the English common law in 1850 existed without requiring a final determination of which controlled in case of conflict until litigation arose over the use of the waters of Kern River in 1881.

Even before the case of Lux vs. Haggin, conflicts between the riparian and appropriation doctrines had arisen. In 1878 the Legislature passed a memorial to Congress urging that riparian rights be withheld for all public lands when patented. This had already been done, in effect, in the Desert Land Act of 1877, although this interpretation of this act was not made by the courts until many years later. In the 1879 Constitutional Convention unsuccessful efforts were made to include restrictive provisions relating to riparian rights.

Lux vs. Haggin

By 1880 there were two large land interests on Kern River. Miller and Lux had acquired large areas of overflow lands in the "swamp" along the channels of the lower river through which the excess stream flow found its way to Tulare Lake. The Haggin interests had acquired similar large areas of land in the vicinity of Bakersfield and had started construction of canals and use of water on land not riparian to Kern River. A conflict of interest necessarily developed, as there was not sufficient water in Kern River at many times for the irrigation of both of these areas.

The lower riparian landowners brought suit to enjoin diversions by the upper appropriators. This put at issue the question of which system of title to water should prevail in California. The interests involved were large enough to assure a full trial and legal argument of the case. If appropriation principles governed, the upper uses met the requirements of the law, were prior in time to the lower riparian uses and would be entitled to take the amounts required for their beneficial needs. If riparian principles prevailed, riparian uses would have to be met before water could be taken for upper nonriparian land.

The action resulting in the decision in Lux vs. Haggin was brought in the Superior Court of Kern County and tried there before Judge Brundage in 1881. The trial lasted forty-nine days; this was a relatively long trial time then, although litigants have done much better (or worse) in several later water cases. In November 1881, Judge Brundage decided the case in favor of the defendants, upholding the upper appropriator as against the lower riparian owner on the ground that only those portions of the English common law had been adopted here that were suitable to California conditions. The case was appealed and extensively argued before the Supreme Court by the best attorneys each side could secure, in the fluent and flowery style then prevalent. The State Supreme Court made a decision in October 1884 with the full bench of seven justices dividing four to three. A rehearing was granted and the case was reargued in March 1885. The final decision, covering 200 pages of the reports, was rendered on April 26, 1886, also by a division of four to three (69 Calif. 255).

The Supreme Court reversed the lower court and upheld the doctrine of riparian rights as the governing rule of water law in California. The case was sent back for retrial on this basis, the retrial to be held in Tulare County. This retrial was not held, however, as on July 28, 1888, the issues between the parties were compromised by a contract generally known as the Miller-Haggin Agreement. This agreement was signed by thirty-one corporations and fifty-eight individuals. It was given judicial standing in 1895 by being made a part of the Shaw decree adjudicating rights on Kern River. It has continued to be the basis for the operation of Kern River.

While the decision in Lux vs. Haggin precipitated arguments over the riparian doctrine and its effect on the development of the state that were active issues for some forty years, the parties at interest in the case found a basis for adjusting their differences after their relative legal positions had been defined. The Miller-Haggin Agreement has served to keep water-right issues on Kern River free from major litigation for the last seventy years.

The Antiriparian Irrigation Organization

California has been agitated several times over public issues relating to its waters, but the activity over riparian rights can well claim to be uppermost in its class. Antiriparian organizations were formed over the state and combined in a state organization. These were started in 1882, prior to the decision in Lux vs. Haggin, when this issue was only a menace and not a reality. An Anti-Riparian Irrigation Club was formed in 1884.

The Articles of Association of the Anti-Riparian Irrigation Organization of the State of California included the following:

"Whereas, attempts are now being made to resurrect the English common law doctrine of riparian rights from the grave to which the will of the people long since consigned it, and to impress it upon the jurisprudence of the State; and, Whereas, such attempts, if successful, means the desolation of thousands of homes; means the desert shall invade vineyard, orchard and field; that the grape shall parch upon the vine, the fruit wither on the tree, and the meadow be cursed with drought; means that silence shall fall upon our busy colonies, and their people shall flee from the thirsty and unwatered lands; means that the cities built upon commerce irrigation has created, shall decay, and that in all this region the pillars of civilization shall fall, and the unprofitable flocks and herds shall graze the scant herbiage where once there was a land of corn and wine, flowing with milk and honey, and,

"Whereas, if this attempt to forbid the useful appropriation of water is defeated by a righteous public opinion crystallized into law, the homes now planted in midst of fruitful acres will remain the shelter of a happy people, enriched by the productive soil, and irrigation will advance the frontier of verdure and flowers and fruits, until the desert is conquested and has exchanged its hot sands for happy garlands, its vagrant herds for valiant people, and the bleak plains grow purple with the vintage and golden with the harvest, and the pleasures and profits, the peace and plenty that come out of the useful rivers, will make this land the Promised Land to millions of free people."

These Articles did not leave much room for hedging on this issue by the members of this Association. Recent trends in similar matters have been toward less positiveness in position. At least there was no need to be in doubt about the stand taken by this group; perhaps better progress would be made toward the solution of present-day water problems if the various interests concerned would declare their positions equally positively.

Effect of Lux vs. Haggin

While a settlement of the issues involved in Lux vs. Haggin insofar as Kern River was concerned was reached by local compromise, the reactions to the principles announced in the Supreme Court decision were statewide. If riparian lands could hold rights to water without use and could demand amounts of water outside of the limitations of the beneficial use of the appropriation system, the riparian doctrine could be used to limit development to riparian lands and to deprive nonriparian lands of an opportunity to secure water except on such terms as the riparian owner might prescribe.

These issues were not small scale nor academic, as there were relatively large ownerships of riparian lands on the lower portions of nearly all streams in the Central Valley and in some other parts of the state. Such large ownerships were acquired through Mexican land grants, by means of the Swamp and Overflow Land Act, or by the use of script. The state could not afford to have such a restriction placed on its future development and attempts were made to overcome the effects of this decision.

The controversy over the Lux vs. Haggin case antidates the present-day proficiency in "information service by public relation specialists," but the record indicates that the issues were more extensively presented and more vigorously argued in the press of the state than is now usual. What the editors wrote represented their own compositions rather than press releases of the parties. The facility of expression as well as its colorfulness exceeded the more professional products of the present time. Newspapers' discussions of this issue are still interesting reading today, even though the heat engendered is now mainly a memory.

As a result of the public clamor over this decision, Governor Stoneman called a special session of the Legislature in August 1886 to consider remedial legislation. There were heated debates over the ability to overcome the effects of the decision by statutory means as well as the form such statutes should take. Bills seeking to re-establish appropriation rights were passed at this session by the Assembly. These bills were not brought to a vote in the Senate, an action equivalent to their defeat.

Following failure to secure a change in the doctrine established in Lux vs. Haggin by legislative means, further control of the issue was left to the courts. Cases involving conflicts between riparian owners and appropriators were frequent in the forty years following Lux vs. Haggin. In general, these confirmed and emphasized the advantages of riparian lands and narrowed the opportunities to secure water for nonriparian use. Individual cases decided by the Supreme Court varied in the degree of their harshness in restricting appropriations where opposed by riparian owners but the general trend favored the riparian rights.

Conditions were not as difficult as they might have been in some cases because riparian owners did not always assert their claims in opposition to upper diversions. While riparian rights had a superiority in the right to use water from a stream, this advantage could be lost by failure to assert such rights or to use water on the riparian lands. Such failure, if continued long enough under conditions of damage to the lower riparian land, resulted in a loss of the right to oppose the upper diversions. Rights acquired by such adverse use or prescription were secured for much irrigation so that development proceeded on many streams. In other cases, settlements were made with lower riparian owners under which upper appropriations were permitted.

The Herminghaus Case

While the conflict of riparian and appropriation rights to the use of water was an active issue in California from the time of the decision in Lux vs. Haggin, it did not reach fever heat again until the Supreme Court of the state finally decided the case of Herminghaus vs. Southern California Edison Company on January 21, 1927 (200 Calif. 81). This decision so aroused public feeling that a basis for a constitutional amendment was found which was adopted and has largely removed this conflict.

Miller and Lux were the principal riparian owners on the San Joaquin River and had actively and, generally successfully, prevented the establishment of upper appropriation rights. When earlier power companies desired to develop power on the upper tributaries of the San Joaquin River, they sought and secured an agreement with Miller and Lux permitting such power development under defined conditions and limitations. Based on this agreement, power development proceeded. Similar agreements were secured by the power company with some but not all of the remaining riparian owners.

The Herminghaus lands comprised about 18,000 acres riparian to the San Joaquin River, mainly between the river and Fresno Slough. At times of high stages in the river, water entered the Herminghaus lands through various sloughs and produced pasturage on the overflow lands. No constructed diversion works were in use. Flows in the river of some 5,000 second feet were required to cause flow to enter the principal sloughs. These lands had been rented for many years at $1.00 per acre per year with the owner paying the taxes.

When the Southern California Edison Company acquired the earlier power plants and storage on the San Joaquin River and had an extensive program for their expansion under construction, the owners of the Herminghaus lands brought suit to enjoin any interference with the flow of the river past their lands. Some early power uses had acquired title by prescription and public use had occurred on some other power plants so that recovery was limited to the damages resulting from the later projects. The case was directed mainly against work under construction and not in actual use at the time the suit was filed.

This case was tried in Fresno County and a decision favorable to Herminghaus was rendered. This was appealed to the state Supreme Court, which upheld the lower court in a decision which went to much greater extremes in supporting riparian rights than previous cases. It was again held that such a lower riparian owner was not limited to any measure of reasonableness in the use of water in controversies with an appropriator. The power company was enjoined from storing water at any time, even though the water let down would be used only to create sufficient depth of flow in the river to cause natural overflow of the Herminghaus lands. The testimony in the case showed that the demands of these lands under usual practice would be about 180 second feet and that a flow in the river of about 5,000 second feet would be required to supply natural inflow at the slough headings.

This decision was so detrimental to the best development of the state that many interests joined in an application for a rehearing. The court granted a hearing on whether the case should be reopened. Many briefs were presented by water interests, including the state attorney general. The application for rehearing was denied by a decision of the court of four to three. This had the effect of confirming the original decision.

The Herminghaus case also involved the right of a riparian owner to store water. Overnight storage to create a supply for daytime operation of the grist mills was a well-established element in the English common law. A similar

right in forebay storage has been recognized in California. The courts have, however, refused to expand this right to include storage for future use as this practice has been held to be outside the riparian rights as developed in the common law. This has importance to the appropriation rights in the valley, as otherwise the upper power storage might claim to be riparian and not subject to the prior rights of lower uses.

The 1928 Constitutional Amendment

The need to overcome the results of the Herminghaus case resulted in the passage of a constitutional amendment by the 1927 Legislature. After an active campaign in its support, this was approved at the general election in 1928 and is now Article XIV, Section 3, of the constitution. It provides that all uses of water shall be limited by reasonableness and that riparian rights must show reasonable needs and methods of use to be entitled to prevent use by others. This amendment has been before the Supreme Court in a series of cases, in all of which the principle involved has been upheld and the conditions of its application to each case specified. Riparian owners are now subject to the requirement of reasonable use. This amendment has eliminated the ability of riparian owners to prevent use by others merely to have the water left in stream "for the pleasure of its prospect." Since the adoption of this amendment and the decisions upholding it, conditions affecting acquirement of water rights have been stabilized and litigation materially reduced. Thus some seventy-five years after statehood and forty years after the decision in Lux vs. Haggin, a way was found to overcome the difficulties resulting from the adoption of the common law on riparian rights in an area having physical conditions to which it was not applicable. The need for such action was statewide and local and sectional differences were not a factor in reaching a solution.

The 1928 amendment was carefully and clearly worded. It sets forth the policy of the state in relation to all uses of water in a brief form. Its complete text is as follows:

"It is hereby declared that because of the conditions prevailing in this state the general welfare requires that the water resources of the state be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. The right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water. Riparian rights in a stream or water course attach to, but to no more than so much of the flow thereof as may be required or used consistently with this section, for the purpose for which such lands, are, or may be made adaptable, in view of such reasonable and beneficial uses; provided, however, that nothing herein contained shall be construed as depriving any riparian owner of his reasonable use of water of the stream to which his land is riparian under reasonable methods of diversion and use, or of depriving any appropriator of water to which he is lawfully entitled. This section shall be self-executing, and the legislature may also enact laws in the furtherance of the policy in this section contained."

The opposition to riparian rights did not mean that the public interest was any less well served by the use of water of riparian land than on other areas. The opposition was based on the freedom of riparian rights from the require-

ments of beneficial use and priority of use. Semiarid areas cannot afford to have their development handicapped by any procedure that results in waste in the use of its limited water supplies. Riparian owners still have the advantage resulting from their riparian position but cannot use this advantage to hold water not needed or not used on their land.

The 1928 amendment makes reasonableness a principal standard by which use of water by conflicting interests is to be judged. Reasonableness is a question of fact in each case. In recognition of this, the State Supreme Court, in sending some water cases back for final settlement by the Superior courts, has suggested that the parties reach an agreement among themselves on their rights or that they utilize the services of the State Engineer in reaching a physical solution of their controversies. It has come to be recognized that the settlement of water-right conflicts can be made more effectively for all parties at less expense and in less time through negotiations by the parties than can be secured by lengthy trials under the technical rules of judicial procedure. Such physical settlements have been made in several controversies. It is to be hoped that the adjustment of water controversies outside of court will be used to an increasing extent in the future.

The question has been frequently asked as to why the difficulties resulting from the decision in Lux vs. Haggin could not have been avoided by the passage of legislation nullifying its effect. If such legislation could have accomplished this effect, it probably would have had sufficient support to have resulted in its prompt passage. Water rights are a form of real property and when once recognized cannot be taken away except by due process of law, which, in a practical sense, means compensation to the one from whom they would be taken. Riparian rights have value to riparian land and, having been recognized and established by the courts, are entitled to the protection of the law. California could have refused to recognize riparian rights on the ground that they were a part of the common law based on different conditions than existed here, but, once having adopted the common law in general, when the courts held this adoption included riparian rights, it was too late to annul them by statutory action. The same situation exists in regard to the system of title now recognized in ground water; this cannot be changed to an extent which takes values due to ground water from lands now having such recognized values.

While abrogation of such property rights would conflict with both the state and federal constitutions, relief can be secured under the police powers of the state. All property owned is subject to reasonable regulation in its use in the interest of the public. Reasonable zoning ordinances are illustrations of such restrictions on use without confiscation of the value. The 1928 constitutional amendment is based on the police power of the state to regulate the use of water in the interest of the state. It declares the public interest in the reasonable use of water for all forms of use and is not discriminatory against any type of use or right. It is on this basis that the courts have held that the 1928 amendment does not violate other constitutional provisions.

Water-Right Litigation

Water-right litigation in California has been extensive and expensive. The costs include the actual expenses of the various lawsuits and the losses sustained through delays in development and use of water. Such suits have included both "large" and small cases. No complete record of their number has been made; it would serve little useful purpose to compile such a list. A few particular results will serve as illustrations.

The Lindsay-Strathmore Irrigation District in Tulare County was formed

to include citrus areas when their ground water supply became depleted. The district acquired lands adjacent to the Kaweah River and developed water from wells there which was conveyed to the lands in the district. Suit to enjoin such diversion was brought in 1916. It was tried and retried at various times; seven different judges had been assigned to the case before it reached the final Superior Court decision which was appealed to the Supreme Court. This appeal was decided in 1935 (3 Calif.(2d) 489). Following this decision an adjustment was made between the parties; under its terms the district was permitted to use certain of the waters at issue until they could secure water from the Central Valley Project. It is reported that the costs of this case were $600,000 by 1924 and over $1,000,000 by the time of the final court decision.

The deficient runoff of 1920 resulted in shortages for the irrigation of rice in the Sacramento Valley. The diversions for such use aggravated the salt-water intrusion conditions in the Delta. Litigation which came to be known as the Antioch suit was initiated by Delta interests to determine the relative rights of the areas dependent upon the waters of the main Central Valley streams. The costs of the suit are reported to have been $250,000. The decision, made in 1923, did not settle the basic issues involved. Another suit was filed, in which all users in the Sacramento and the San Joaquin valleys of water tributary to the Delta were made parties. This suit has not been tried.

In 1918 a study of litigation in Kings River found 137 cases that had been filed between various users of this stream. Thirty-six of these cases had gone to judgments which affected the operations of the river. There is no record of the total cost of all of this litigation but it was necessarily large. Even these costs did not settle the division of the waters of this stream. As discussed later, such settlement and agreements by negotiations did not occur until the interested parties, by joint action, secured adequate records of their actual diversions and eventually negotiated a water-right agreement. Kings River has been practically free from litigation over water for the past forty years.

J. J. Stevenson owned lands on the east side of the San Joaquin River below diversions by Miller and Lux. The Eastside Canal and Irrigation Company served part of the Stevenson lands. This company was held to be a public utility. In a rate case in 1914 the fair value of the property in use in public service was found to be $110,000. Testimony was also presented that the company had been in continuous litigation for fifteen years over its water rights and that its attorney's costs had been $300,000. In the rate decision the comment was made that, in spite of all of this litigation, the water rights of the company were undefined and still under attack.

The case brought in 1952 by Arizona against California to determine the division of Colorado River water between the lower basin states was submitted to the special master in 1959 after 3,950 exhibits, 6,200,000 words of testimony, and lengthy briefs. The total final costs to all parties have been estimated to be over $4,500,000; about one-third of this total was spent by California.

The Water Commission Act

In addition to the efforts to secure means of controlling riparian rights, attempts were made to secure legislation changing the procedure relating to appropriation rights that would overcome some of the disadvantages of the 1872 statutes relating to the character of records required and limitations on the amounts of water claimed. Posted notices with copies in the county records served early conditions fairly well but were not suited to streams flowing in several counties. This system had no provisions for following up the notice to

see if the works proposed were actually built. There was no limit on the amount of water that could be claimed. The need for some centralized system of record and supervision was evident as soon as development became extensive.

The California Water and Forest Association was organized in 1900 with many distinguished citizens among its officers and members. It assisted financially in an investigation by the U.S. Department of Agriculture under the direction of Elwood Mead. These results were published in 1901 as Bulletin 100 of the Office of Experiment Stations of the U.S. Department of Agriculture. Several California streams were selected for a study of the operations of the notice system for making appropriations of water. These showed many indefinite and incomplete notices with the total amounts claimed on all streams exceeding the maximum recorded flood flows. Many notices claimed the entire flow of the stream; frequently, the amount of water claimed was very much greater than it would be possible to divert in the size of diversion conduit stated in the notice. All of the investigators agreed that this method of initiating titles to the use of water was ineffective.

Legislation embodying the recommendations resulting from this investigation was introduced at the 1903 legislative session. This bill included a general water code and also provisions for the fixing of water rates. Much opposition was encountered and the bill failed to pass. The efforts in behalf of this legislation were helpful in preparing public opinion for later legislation although they did not produce immediate results.

The California State Conservation Commission was created by an act passed in 1911. It consisted of three members appointed by the Governor. It had as its function the investigation of the resources of the state and "systematizing and reforming" the laws of the state relating to these resources. A State Water Commission was also established in 1912 and given jurisdiction over the acquirement of water rights for power purposes. The Legislature in 1913 enacted a general Water Commission Act covering all uses of water. This was delayed by a referendum but was approved at the next general election and became effective on December 19, 1914. This Water Commission Act, with subsequent amendments, is now the basic statute governing appropriation rights in surface streams. Ground waters have not been placed under similar statutory supervision and procedures involving riparian rights are still left mainly to the courts.

The Water Commission Act provided initially for three full-time members. This was later changed to one full-time member and two part-time members until the duties of the Commission were assigned to the State Engineer. In 1956 the acquirement of water rights under the act was placed with the then created Water Rights Board. The Water Commission Act was codified in 1943 as a part of the Water Code. Since 1943 references to the act are usually made by using appropriate Code sections.

The Water Commission Act has three main divisions. These relate (1) to the acquirement of new rights, (2) the definition of old rights, and (3) the administration of all defined rights.

Practice among the western states in the regulation of the use of their waters has become fairly well standardized in its general features. The California statutes conform to these standards with some variations to meet the local conditions. It is generally recognized that the interest of the new appropriator and the state require that the appropriator be able to acquire his right under state inspection and approval so that its record may be officially established as the right is acquired. To protect earlier existing rights, they are given an opportunity to be heard in protest against new rights if they consider they will be injured. It is also generally recognized that the final ob-

jective of any water code is to enable the owner of each right to secure the water to which he is entitled at the time he needs it so that damage to him by adverse diversions does not occur. Prevention of damage is much more valuable than a right to recover damages after they have been inflicted. To be able to administer a stream from day to day, so that each right receives the water to which it is entitled, requires that all rights be defined in terms which can be applied to the daily stream flow. Such a definition of all rights is required before a water master can administer a stream without having to exercise judicial functions.

Like other western states, there were many existing rights in California when the centralized system of state administration was adopted. Thereafter, new rights were defined as they were acquired, but it was necessary to define the older existing rights on each stream before an administrative system for its operation could function. The Water Commission Act provides for such definitions of old rights by procedures initiated by the State Engineer or by reference from the courts for cases initiated there. When the old rights have been adjudicated, the administrative supervision can function continuously as new rights are defined as they are acquired.

Acquirement of New Rights

The Water Commission Act defines the conditions which must be met as a prerequisite to the issuance of a permit. Some of these conditions, such as form and completeness of the application, are specific. Some are discretionary.

The statutes provide that appropriations shall be allowed under terms and conditions which will best develop, conserve, and utilize in the public interest the water sought to be appropriated and also that applications shall be rejected which, in the judgment of the department (now the Water Rights Board), will not best conserve the public interest.

In the earlier years of the administration of the act practically all uses of water which met the other requirements of the act were considered to be in the public interest. Early court decisions restricted any exercise of judicial functions under the act. Following a decision of the State Supreme Court in 1955 that "The department exercises a broad discretion in determining whether the issuance of a permit will best serve the public interest," this provision has been used by the Water Rights Board as granting it authority to reject an application or to grant a permit based on its judgment of the public interest. The Board's interpretation of public interest has been used to outweight priority of application in one contested case. Such actions have been too recent to have reached final review by the courts in appeals from decisions of the Board.

The Water Commission Act also provides that municipal use is the highest type of use of water. Where conflicting applications are filed for different types of use, municipal use takes precedence up to the issuance of the permit. After a permit has been issued, priorities govern over the preferences expressed in the act. The need for municipalities to plan their future water supplies for a longer period before they may be needed than is needed for other forms of use is also recognized. A municipality may appropriate and hold water for its future use; others may use the water until it is needed by the municipality. This represents a special standard of diligence for such municipal use.

Since 1914 all new appropriation rights that may be acquired are subject to the terms of the Water Commission Act. These terms include an application to the state for a permit to construct the works required for the appropriation, a hearing on any protests that may be made, the granting of a permit

if there is available unappropriated water, the fixing of the time for construction and use, and the final granting of a license when the project has been completed. This systematic procedure represents a major improvement over the old notice-posting practice. For small uncontested applications the procedure is simplified so that it is not burdensome on the applicant. New rights are acquired with a complete official history which will avoid the difficulties that many old rights have encountered in later controversies after the individuals handling the early operations were no longer available as witnesses.

Since its enactment in 1914, about 19,000 applications to appropriate water have been made under the Water Commission Act. About two-thirds of these applications have received permits. While the lapsing of one-third of the applications might appear to be a weakness in the functioning of the act, it actually represents one of its advantages. Under the old notice system no record was secured of the later history of each appropriation; an even larger proportion was probably never followed by construction work. A record is now available for all applications until they may be completed as well as of their operation under license.

Applications to Appropriate by the State

When the state began its investigations relating to plans for the ultimate development of the water resources of the state, the Legislature considered some reservation of the remaining unappropriated waters might be needed in order that such waters might be available at the time when the state might be prepared to proceed with state projects. In 1927 the Legislature authorized the State Director of Finance to make applications to appropriate the remaining unappropriated waters that might be needed for state projects which might be built in the future. To January 1, 1959, a total of 142 such applications had been made. In 1927, 27 applications were made for use by the then proposed state's Central Valley Project. Additional applications have been made as the state has become interested in other projects. In 1956, 48 applications were made; 35 of these were on north coastal streams. In 1958, 24 applications were filed, 8 on the Walker River, 10 on the American River, and the remainder on other streams. These state applications now cover nearly all of the remaining larger sources of unappropriated waters in the state.

In authorizing these state applications, the Legislature recognized that the unappropriated waters, for which the applications were made, should not be withdrawn from all use by others and that projects which might be proposed for present construction, which would not conflict with the proposed future use by the state, should be permitted to proceed. The Director of Finance was authorized to assign such state filings or to make releases from the state's priorities to other agencies proposing uses not in conflict with the state's program. To January 1, 1959, 10 releases from priority covering 22 applications have been made in favor of projects which have proposed developments at different sites on the stream or have contemplated different service areas. Twelve assignments covering 21 applications have been made to January 1, 1959, where another agency has planned to build a project essentially as proposed in the state application. Nine of these assignments covering 17 applications have been made to the U.S. Bureau of Reclamation for works which it has constructed as a part of the federal Central Valley Project. In 1956, these functions, originally assigned to the Director of Finance, were transferred to the Director of Water Resources, and in 1959 they were assigned to the California Water Commission.

Where state applications have been made, other applicants for the same unappropriated water are now subject to dual procedures. Releases or assign-

ments must be sought from the California Water Commission and the requirements of the Water Rights Board must also be met. The Water Rights Board, in determining the public interest in its action on applications, is now directed to "give consideration to any general or co-ordinated plan looking toward the control, protection, development, utilization, and conservation of the water resources of the State, including the California Water Plan, prepared and published by the Department of Water Resources or any predecessor thereof and any modification thereto as may be adopted by the department or as may be adopted by the Legislature."

The present requirements for the appropriation of water by agencies other than the state represent a wide departure from the procedures during the past hundred years. Under the early notice system there was no control or regulation of the acquirement of water rights. The Water Commission Act established a central office of record and defined the factual material that must be supplied. In the earlier years of the Water Commission Act the courts limited its functions to ministerial duties relating to determining the availability of unappropriated water and the completeness of the application. This has now been changed to a permissive system where the granting or rejection of an application depends on whether it may conflict with some future program for construction by the state and on whether it conforms to the conclusions of the members of the Water Rights Board regarding the public interest.

Public interest is intended to represent the overall interests of the public. In specific cases there can be a wide range of conclusions regarding how the public interest may best be served. There is no tangible basis on which the public interest in a project now nearly ready to proceed can be balanced against the public interest in some future plan which may or may not be built.

From 1956 to 1959 acquirement of a permit by others than the state to appropriate any of the unappropriated waters of the state covered by state applications depended on the permission of the state agency having its own plans for the use of these waters, with this interested agency, the Department of Water Resources, acting as the judge of whether the other proposed use conflicted with its own future plans. This condition was changed in 1959 by transferring all state applications to the present California Water Commission. This California Water Commission is the successor of the former State Water Resources Board and has no relation to the State Water Commission which administered the original Water Commission Act. The present California Water Commission is advisory to the Director of the Department of Water Resources in its other functions but has independent authority in its actions on assignments and releases of state applications. The State Water Rights Board is to include the terms of any releases or assignments of state applications made by the California Water Commission in the terms of permits to others seeking the use of the released or assigned water.

This 1959 legislation is an improvement over the procedure in effect from 1956 to 1959 but still leaves the applicant for other uses of water covered by state applications subject to a dual jurisdiction and double hearings. Hearings are to be held on granting releases or assignments by the California Water Commission and will also be held by the State Water Rights Board on other matters relating to the application. Placing both of these procedures with the State Water Rights Board would expedite results and reduce costs to the applicant as well as placing the decision in an agency, outside of the Department of Water Resources, which has administrative jurisdiction relating to the acquirement of water rights.

Preferences to Areas of Origin

The 1927 Legislature, in the statute authorizing applications to appropriate by the Director of Finance and the release or assignment of such applications to others, included a provision that no releases or assignments should be made which would deprive the county in which the appropriated water originates of water necessary for the development of the county. This provision (Sec. 10505 of Water Code) is the extensively discussed "county of origin preference."

In 1933 the Legislature also passed what are now Sections 11460 to 11463 of the Water Code, creating similar preferences to drainage areas of origin or areas immediately adjacent thereto which can conveniently be supplied with water therefrom. This is generally referred to as the drainage area of origin preference. This provision is a part of the Water Project Authority Act and applies only to the construction and operation of projects by this Authority, which was succeeded by the Department of Water Resources in 1956.

These statutes require the California Water Commission, in making assignments or releases of state filings, to make reservations for the future needs of the counties of origin. The reservations for the drainage areas of origin (Code Section 11460 to 11463) were originally applicable only to projects to be built by the state. In 1951 the Legislature made these sections applicable also to the projects of any agency of the state or the federal government (Code Section 11128).

The State Water Rights Board, in issuing permits to applicants who have secured releases or assignments of state applications, includes the terms of the releases or assignments as conditions in the permit. The Board may also include reservations for the area of origin in its permit terms under its determination of the public interest. Reservations which have been made by the Board have included a defined amount and time limit on the water reserved for use above the Monticello Reservoir on Putah Creek. On the American River a reservation for the reasonable beneficial use within the watershed tributary to Folsom Reservoir was made without a limit on its amount or the time within which it is to be used.

The right to appropriate water from one drainage area for use in other areas was recognized in the 1872 statutes and has continued to be recognized for all but the public agencies specified in Section 11128. With its applications now covering nearly all of the remaining unappropriated waters of the state, the state is now in a position to enforce area of origin preferences on nearly all future appropriations.

Preference to drainage areas of origin have a physical basis in that the drainage areas are definite topographic units related to the water supply. County lines are the result of early settlement. They may, but in some cases do not, have any relationship to the areas producing the water supply. A county of origin may include several drainage areas. Lassen County includes areas in the Feather River drainage and also areas in the Great Basin. There is no sound basis for preventing use of Feather River water in the lower counties of its drainage area by creating a reservation for its use in the Great Basin. Projects in the Sacramento Valley are within its drainage area but are counties of origin to only a limited extent.

These statutory reservations for the areas of origin are not limited by any time period and remove the areas of origin from any requirements of diligence in using the reserved waters. As the principal areas securing such preferences are those in which the early uses of water were for mining, with its requirements for diligence and beneficial use, these preferences represent a reversal of the principles which originated in these areas.

California's attempt to create preferences to counties of origin is contra-

dictory to its position relating to interstate streams. It has not recognized the right of Oregon to all of the flow of the Klamath River, which originates in Oregon, and is not attempting to secure all of the water originating in California which drains into Nevada. California does not concede the right of the upper Colorado River states to all of the runoff originating in their areas.

The United States Supreme Court has held that a state of origin does not have rights to all of the water originating within its area as against a lower state (Wyoming v. Colorado 42 S.Ct. 552). State boundaries have a higher governmental status than county lines.

The county of origin statutes have not as yet been before the courts for interpretation. Like all uses of water in California, any rights claimed under the county of origin preference are required to meet the standards of reasonable use prescribed in the 1928 constitutional amendment. Reservations for future undefined uses which are unlimited in time or amount have questionable reasonableness. The present county of origin statutes attempt to create in the upper counties of drainage areas a type of water right which does not require diligence or reasonableness in its beneficial use of water. This is the same type of opportunity to extract payment from other uses for releases by such preference areas that the 1928 constitutional amendment sought to take away from lower riparian owners.

Any attempted reservations to areas of origin can only be applicable to the remaining unappropriated water at the time the reservation is made. Water to which rights have been acquired cannot be recaptured for use in the area of origin except upon payment for its value. As the dependable flow of most of the streams originating in the counties most assertive of their county of origin preference has already become vested in lower uses, the physical effects of such preferences will be much less than it would have been at an earlier stage in the state's development. The remaining unappropriated water in the counties of origin will require storage for its regulation and use. The costs of such storage and other project works, together with the climatic restrictions on crop returns, has delayed extensive local use of water for irrigation in these mountain counties. These conditions will continue to retard development in these areas.

While the issues relating to drainage areas and counties of origin have been among the most vociferously supported of the matters relating to the use of the state's remaining unappropriated water, the probable actual result of any such preferences in the upper drainage areas will not be large enough to affect materially the development of the state's water resources. In its investigations of the upper drainage area of the Feather River, the state has found only limited amounts of probable future development. Much of the future storage in these upper areas will be for recreation rather than for irrigation. Recreation consumes water to only a limited extent and nearly all of the water developed by such projects will be available for reuse in lower areas. The political aspects of the county of origin issue have been amplified beyond their prospective actual effects on the development of the state's water resources.

Senate Bill 1327 (chapter 1766) enacted by the 1959 Legislature defined the area of the Sacramento–San Joaquin Delta and found the maintenance of an adequate water supply in the Delta to be necessary for the peace, health, safety, and welfare of the state. Salinity control and an adequate water supply for use in the Delta were declared to be among the functions to be provided by the State Water Resources Development System and no water necessary to meet these requirements is to be exported from the Delta. This legislation attempts to make meeting the requirements of the Delta for its water supply and for salinity control a prior demand on waters reaching the Delta. The degree of salinity control to be provided is not defined in Senate Bill 1327.

Adjudication and Administration of Rights

Adjudications under the Water Commission Act in California have not been as extensive as those in other western states having similar statutes. This is the result of the complications resulting from riparian rights in California and also of the greater extent to which the larger water rights on the major streams have been defined by court procedure. The adjudications under the act have been confined mainly to streams in the higher valleys. The limited activity in adjudications under the Water Commission Act has also limited the extent water masters have been used to administer diversions.

While water masters appointed under the provisions of the Water Commission Act have not been operating on the larger streams, there are two such operations under agreement of the parties involved which have been successfully functioning on a voluntary basis. These are the Sacramento and San Joaquin rivers and Kings River.

Following the decision in the original Antioch suit relating to the rights of lands in the Sacramento–San Joaquin Delta and diversions from its tributary streams, a more general suit including all users was filed. In 1924 there was a major deficiency in runoff which was foreseen by January of that year as a result of the very limited precipitation. A conference of interested parties was called and arrangements were made to have the state secure records of the use by all diversions affecting the Delta. The Sacramento–San Joaquin River Problems Conference was formed to represent the water users. A state-selected Water Supervisor was appointed to make the desired measurements. This arrangement has been continued to date. Annual reports covering the stream flow and diversions are issued. Special studies of salt-water intrusion, and its damages, and consumptive use in the Delta have been made.

One of the objectives of this work was the ultimate definition of the relative right of all users from these streams. It was recognized that any such adjudication would require much more information on actual use than was available in 1924. The Water Supervisor has no legal authority to regulate diversions and, until such an adjudication may be completed, there is no basis on which he could be given such authority other than the voluntary consent of each diversion to be regulated. The main purpose of this work has been the collection of adequate records by a qualified, but neutral, agency. This purpose has been well accomplished and this undertaking represents a very creditable example of the ability of water users having inherent conflicts to work together in matters of common interest. While the Water Supervisor has no legal authority to control use, he has been able to secure more effective use of water at times of shortages by cooperation and persuasion.

Similar need for impartial records of the diversions from Kings River was recognized and a state-selected water master was appointed for this purpose in 1918 at the request of the local interests. The results obtained led, in 1927, to an agreement between the larger number of the local units defining their relative rights as between the parties to this agreement. This agreement was extended in 1949 to include nearly all users. The water master has administered these agreements since 1927. This represents, in effect, an adjudication of these rights by negotiation and consent of the parties thereto as a substitute for similar results which might have been obtained by a contested adjudication.

Results of State Administration of Water Rights

The Water Commission Act has been in effect for about forty-five years. It can now be judged on its record. On the positive side, new water rights are supervised and their records maintained in a central state office. Adjudications

have been made where these have been needed and water masters function on the adjudicated streams.

The Division of Water Resources performed its duties under the Water Commission Act until its interests became centered on its investigations of a state water plan. From about 1930 to the reorganization in 1956, applications to appropriate were processed as to form but hearings on contested applications were allowed to lag.

The Water Commission Act makes procedure under its terms the exclusive method of acquiring appropriation rights and diversion, except in compliance with the act, is unlawful. Such compliance requires securing a permit before diversion can begin. The U.S. Bureau of Reclamation completed and operated the Shasta and Friant reservoirs without action by the Division on their applications to appropriate. There was similar laxness in acting on some other applications.

When the present Water Rights Board was established in 1956, there was a large backlog of contested applications on which hearings were required before permits could be granted. The Board has undertaken to overcome this accumulated work and has made progress in its reduction. The hearings on the larger streams have been prolonged. Over one hundred days of hearing, extending over a total period of a year, were held on the conflicting applications on the San Joaquin River. A major part of the support for the passage of the Water Commission Act was the hope that its authority to make its own investigations would shorten the time and expense of its hearings and avoid the delays and costs of court litigation. The Board has permitted the introduction of exhibits and testimony under liberal rules regarding its admissibility to an extent that has prolonged its hearings and increased their costs. As the decisions of the Board may be appealed to the courts, there are only limited advantages in the Board hearing procedure over initial proceedings in court, unless it results in a more efficiently obtained record of the facts.

Supervision of Dams

The St. Francis Dam on San Francisquito Creek was completed in 1926. Its principal function was to provide terminal storage for the Owens River supply of the City of Los Angeles. Rights to use the runoff of its drainage area had not been secured and such flow was passed through the reservoir to those having rights to its use. The reservoir was operated for these purposes until March 12, 1928, when the dam suddenly failed.

The failure occurred practically without warning. The sudden collapse released the stored water into the canyon of San Francisquito Creek in a wave which had a depth of about 125 feet three-fourths of a mile below the dam. This wave carried away the concrete powerhouse one and one-half miles below the dam. The flood followed down the creek for nine miles to the Santa Clara River, which it followed for nearly forty-five miles to the ocean. Records indicate that the flood wave had velocities of eighteen miles per hour near the dam and five miles per hour near the ocean. The maximum rate of flow just below the dam was estimated as over 500,000 cubic feet per second, thus approaching the maximum flood flows of the entire Sacramento Valley. The suddenness of the failure gave no time for warnings in the path of the flood near the dam. Known dead numbered 236, with about 200 missing.

Several investigations of the cause of the failure were made. A board of engineers and geologists was appointed by the state. Their conclusions were in general agreement with those reached in other investigations. While individual opinions differed in regard to details in the causes and the sequence of events leading to the failure, it was generally agreed that weaknesses in the foundations caused the failure and that the design of the concrete dam and its

construction were not at fault. Much of the foundation consisted of a conglomerate which, when dry, appeared hard and strong but which, when wet, became soft and inadequate to support the dam or to confine the water stored.

Few events relating to the development of water in California have produced the shock to the public that resulted from this failure. The aggressive seeking and securing of water to meet the rapidly growing needs of the city and the outstanding record made in bringing in outside sources of supply, from what were then record-breaking distances, had given Los Angeles a unique position in the municipal water-supply field. Practically all of this development had occurred under the leadership and direction of William Mulholland. He had acquired and earned the respect and admiration of the engineering profession for his ability and rugged honesty. It was difficult to believe that a major structure on this system had failed.

With the same aggressiveness and ability that had been used to build the Owens River system, Los Angeles assumed responsibility for the failure of the St. Francis Dam and undertook the restoration of the physical damages and reparations for the loss of life. To the credit of all concerned, practically all claims were adjusted without litigation. Lands covered by eroded material deposited by the flood wave were restored where practicable. The value of the city's property destroyed was about $1,800,000. In addition, over $8,000,000 was expended in payment of claims and other expenditures resulting from the failure of the dam.

There had also been failures of dams in California, other than early dams for mining, but none with loss of life. A slide occurred during the construction of the Calaveras Dam of the Spring Valley Water Company supplying San Francisco which required reconstruction of much of the work. The Lower Otay rock-fill dam in San Diego County was overtopped by a flood in 1916 and failed. Sixteen failures since 1900 were found in investigations by the State Engineer. Seven of these failures were the result of overtopping, two of defects in the outlet structure, and two of improper spillways. Only one failure was found that was charged to an earthquake.

At its next session following the failure of the St. Francis Dam, the Legislature passed an act requiring applications to be made to the state and permits to be secured before dams impounding water to depths in excess of specified minimum amounts could be built. This act has functioned successfully since its passage. Plans for dams are submitted to the State Engineer, approval is secured prior to construction, and frequent inspection, where needed, is made during construction. This act also gave the state authority to require repairs and improvements in dams built at the time it was passed. Inspection continues after completion of construction and storage may be limited at any time by the state if it finds conditions unsafe. There have been no failures of dams in California coming within the scope of this act since its enactment. While the failure of the St. Francis Dam would have resulted in more thorough care in selecting and preparing the foundations of dams and in their design and construction even without such state legislation, much of the credit for the favorable record since 1928 can be given to the state supervision of dams. There are over 600 dams in the state which come within the provisions of this act.

Organization of the State's Water Functions

The increasing interest in the water resources of the state led to the creation of the office of State Engineer in 1878. William Ham Hall was the first State Engineer and conducted active investigations until 1887, when reduction in appropriations for his office resulted in its abolishment. His reports based on this work contain basic information that is still useful.

The Department of Engineering of the state was created by the Legislature

in 1907. It remained as a department until 1921, when it became a division of the then created Department of Public Works. The 1921 act provided for Divisions of Highways, Engineering and Irrigation, Water Rights, Land Settlement, and Architecture. In 1923 the Divisions of Highways and Land Settlement were removed from the Department of Public Works and the Chief of the Division of Engineering and Irrigation was made the Director of Public Works with the title of State Engineer. This basis was continued until 1927, when the Division of Highways was again made a part of the Department of Public Works, with its chief the director of the department.

This form of organization was continued until 1956, when a separate Department of Water Resources was established. A State Water Rights Board was also created to handle acquirement and adjudication of water rights. This reorganization resulted from the expanding activities of the state in the planning of future water development and the expected entrance of the state into the construction of water projects.

It was recognized that, if the state should construct projects, conflicts might arise between the state and other water projects and that the state agency constructing its projects would be an interested party and should be disqualified from acting judicially in such procedures. The reorganization to date has only placed with the Water Rights Board the functions relating to the definition of title to the use of water. The administration of defined rights also requires an impartial agency; to date, such administration has been left with the Department of Water Resources. It is essential that such administration of water rights be placed in an agency independent of the state construction agency before a state program of project construction reaches the operating stage.

From 1907 to 1950 there had been only four State Engineers, two of these served the greater part of this time. William F. McClure was State Engineer from 1912 to his death in 1926. Edward F. Hyatt served from 1927 to 1950. Mr. McClure guided this office during the revived activity in irrigation district formation and financing. Mr. Hyatt served during the period when planning for the coordinated development of the state's water resources was undertaken. Although only two governors have served for more than one term during this period, the tenure of the State Engineer was not disturbed by changes in the state administration. This resulted in continuity of policies and personnel in matters of water policy and administration. The position of the state official representing any western state in its functions relating to its water resources is an important part of the state government. In some other western states this has not been recognized as fully as in California. Few of the similar officials of the other states have been given the support required to enable them to supply the type of engineering service these states require. California has maintained and supported an adequate and capable staff in this branch of its government which has fully repaid its cost in the value of its services. A. D. Edmonston was State Engineer from 1950 to 1955, during the preparation of the report on the State Water Plan. Harvey O. Banks has been State Engineer and later the Director of the Department of Water Resources from 1955 to date.

The activities of the State Department of Water Resources include investigations of the water resources of the state and the preparation of plans for their coordinated development, the administration of portions of the Water Commission Act and the supervision of dams. In addition, the director is a member of the California Districts Securities Commission and directs its engineering functions. The department is also assigned the maintenance of the Sacramento and San Joaquin Drainage District and the participation by the

state in flood-control projects. Other special assignments have been made by the Legislature from time to time.

A State Water Resources Board was created by the Legislature in 1945 to represent the state in matters of policy relating to the water resources of the state and in its participation in the costs of federal flood-control projects. Its initial functions were mainly advisory; these were enlarged in 1947 to enable the Board to initiate investigations. This Board issued the reports on the state water resources until it was changed to the California Water Commission in the 1956 reorganization and made advisory to the Director of the Department of Water Resources.

Ground Waters

Rights to the use of ground water have also been the source of extensive litigation in California. This is the result of the difficulties in determining the physical conditions affecting such waters as well as conflicts in the interpretations of the legal principles governing the rights to their use. There are elements of similarity between the history of water rights in surface streams and in ground waters. Fortunately, the controlling ground water case did not arise until the decision in Lux vs. Haggin regarding surface streams had been made and its undesirable effects experienced so that similar results could be and were avoided for ground waters.

Extensive use of ground water, with its resulting controversies, did not occur until near the end of the Nineteenth Century. If the adoption of the English common law included the adoption of the English common law doctrine of riparian rights on surface streams, then presumably it also included the English common law doctrine on ground waters. In England the owner of the title to land owned everything under his land, including ground water, and could extract it as he might desire without recourse by his neighbor. Under this principle, no amount of ground water use by one owner could constitute a legal damage to his neighbor, as any owner was free to secure all the water he could from under his land.

The English common law rule on ground water operates simply and fairly equitably in areas having good ground water replenishment and limited draft. It is still followed in many of the eastern states where these conditions occur. It fails, however, to distinguish between the conditions applicable to fixed minerals and those affecting fluid contents of soils. Removal of rock or mineral ores from under land does not induce movement of such materials from adjacent lands. This is not the case with water.

Whenever ground water drafts have become large, inequities occurring under the English common law have resulted and it has been modified in a number of states to meet the actual conditions. These modifications have been of various kinds and degrees in the different states. The experience of California in this regard is similar to that of other states, both eastern and western. Such modifications, where required to meet the physical conditions of the area in which they are applied, are an inherent part of the English common law which, itself, is the outgrowth of the customs developed to fit the conditions of its area.

A case on ground water, comparable to Lux vs. Haggin on surface streams, arose in southern California. This reached the Supreme Court as Katz vs. Walkinshaw (141 Cal. 116), decided in 1903.

In its decision in this case the Supreme Court examined the conditions relating to ground water and its use. It held the English common law was not applicable to the physical conditions here and rejected it as the rule in California. It adopted rules which it concluded would be best suited and most equitable. These rules are still followed. Their principles have come to be known as the California rule of reasonable use or the rule of correlative rights.

Under the principles defined in Katz vs. Walkinshaw and in succeeding amplifying decisions, it is now well established that in California each landowner whose land overlies a supply of ground water has a right in the use of such water to an extent that is reasonable in relation to the needs of other overlying owners. If the available supply is insufficient for the needs of all overlying owners, each such owner is entitled to have the supply apportioned on the basis of reasonableness. If some overlying owners do not use their share of the supply, it may be used proportionately by those who are using water. The maximum right of an overlying owner is limited by his reasonable needs. If the amount of the supply exceeds the needs of the overlying owners, the surplus may be taken to distant or nonoverlying lands. Among different distant takers, the rules of appropriation generally govern, including priority of use and the limitations of beneficial use.

This system enables the available supply of ground water to be divided equitably among the overlying owners with protection to them in a supply adequate for their needs before others may take water to nonoverlying lands. It does not permit overlying owners, however, to prevent use by others of any surplus waters.

The principles established by the court have been a material factor in the extensive ground water development that has taken place in California. This system is not perfect; no system that deals with obscure matters, such as safe yield of ground water supplies, can be expected to work perfectly. It is an equitable system, particularly as between overlying and distant users. It resembles the riparian doctrine on surface streams in that a preference based on position is included, but it differs from the earlier riparian doctrine in that such preference extends only to the reasonable needs. It is weakest in not providing means by which prior users among overlying owners may protect their priority of use and investment against sharing the available supply with later overlying users where the total supply is less than the needs of the overlying lands.

Like the riparian rights on surface streams, the correlative doctrine for ground waters, when once recognized and established, become a property right of the overlying land which cannot be taken away except by due process of law. Such process normally means compensation where the taking results in a reduction in the property value. Such rights are subject to reasonable regulation under the police power and such regulation is provided for in the general 1928 constitutional amendment applying reasonable use to all waters.

Although the overlying owners have a correlative right in the ground water supply under their lands, until recently there had been only limited efforts made to secure apportionments of the available supply among overlying owners. Even where material depletion had occurred, the overlying owners had generally preferred to leave the outcome of any resulting conflict to determination by what may be termed economic competition. Such overdraft results in ground water lowering which, in time, forces the less economic uses of water to abandon their pumping. When such abandonment has proceeded far enough, the remaining draft may be reduced to the safe yield of the ground water supply. In recent years ground water apportionment has been made in the Raymond Basin at Pasadena (33 Calif. (2d) 908, 1949) and one is being completed in the West Coast Basin near Los Angeles.

In the early development of ground water in California, flowing artesian wells were obtainable in many areas. These areas included much of the coastal plain of southern California, the trough lands of the San Joaquin Valley, and much of the area surrounding San Francisco Bay. The term "artesian," as used popularly, is a well which flows under the natural pressure of the ground

water. Earlier artesian wells, in some cases, had sufficient pressure to supply domestic water in the second story of houses. There are almost no flowing wells now remaining, as the ground water draft has depleted the supply and pressure so that flow no longer occurs. Some wells pumped to secure greater draft during the irrigation season may recover and flow during the winter months.

Unless an artesian well is closed when its delivery is not needed, waste occurs. To prevent the resulting depletion of such supplies, the Legislature in 1877, with amendments in 1901 and 1907, made such waste a misdemeanor and required the capping of all artesian wells and their closing when not in use. This restriction has been upheld by the courts as a proper exercise of the police power. The use of artesian flow for purposes of limited benefit, such as flooding duck ponds, is also prohibited by ordinances in some counties.

There has been extensive litigation over rights to the use of ground water. This has been largely where taking of water to distant areas has been involved. Such cases are difficult ones for the courts, as the controversies involve determinations of the amounts of water available as well as the application of principles of law. The measurement of ground water sources is necessarily subject to more uncertainty than similar measurement of surface streams. There are now recognized methods for determining the quantities of ground water which may be extracted from a given area without overdraft, and the general limits of the safe yields of many of the ground water basins of the state have been worked out. Detailed observations over many years are required in order to secure such results. In view of the difficulties in presenting such information under the limitations of court evidence, there has been an increasing trend toward using the neutral services of state or federal agencies in making such investigations.

There is no economic lift which can be defined and applied to determine the extent to which depletion may proceed before abandonment occurs. In periods of low crop prices, suspension of operation for annual crops occurs under relatively low lifts; there were many such abandonments in pumping for alfalfa during the depression of the 1930's. In contrast, new plants were installed in areas of high lift and rapidly lowering ground water under the incentive of the high crop prices resulting from World War II. Pumping may be profitable in an area of deficient replenishment if the net return exceeds the investment before the ground water may become depleted. This represents a form of mining the ground water that may have taken centuries to accumulate.

The draft on many ground water supplies in California has reached the overdraft stage. In some of these areas the pumping lift has not as yet reached the economic limit and the draft has not been reduced. In other areas abandonment of part of the draft has occurred. An overlying owner who has developed his land and installed a well and pumping plant will normally continue operation as long as the returns meet his out-of-pocket costs. Having made his capital investment, he can and will continue operation even after he may not be able to secure an interest return on the costs of his development.

To date, actual exhaustion of ground water supplies has occurred in relatively few areas. The depths of porous fill in nearly all California ground water areas exceeds the economic lift so that pumping ceases before the ground supply has been fully withdrawn. The alluvial fills in many areas are over 1,000 feet deep and physical depletion is not to be expected in such areas. Near the margins of the valley fill, depth to bedrock may be only 100 to 200 feet and actual exhaustion has occurred in some such areas.

Where the natural ground water supplies may not be sufficient to meet the desired draft, artificial recharge may be used; such water spreading is a

usual and recognized practice. It has produced helpful results in several areas. Flood flows which would otherwise pass over the absorbent area may be spread over adjacent lands to secure their absorption and percolation to the ground water. Such water spreading has been done by agencies representing all users of the ground water supplies being replenished so that conflicts relating to separate titles to natural and artificial ground waters have not as yet reached the courts.

Flow in surface streams and in the adjacent ground waters are frequently closely related. Some streams contribute to the ground water by percolation from their channels; other streams are fed by seepage into their channels from the adjacent ground water. A given stream may lose its flow on the upper portion of its alluvial fill and be fed by seepage in some lower portion of its course. The San Gabriel River is an illustration of this condition; it is a losing stream near the foothills and gains by the rising waters above Whittier Narrows. Small flows may be entirely absorbed; flood flows pass over the entire valley.

The draft in some areas adjacent to the coast has lowered the ground water below sea level. Such lowering always results in a danger of salt-water intrusion. Nine areas of known sea-water intrusion are discussed in Bulletin 63 of the State Department of Water Resources. Preventive measures by means of increased recharge with fresh water or reduced draft are being attempted in some areas.

State Versus Federal Control of Water

Prior to 1900 the federal government undertook few activities that required the use of water. When it entered the field of irrigation by the construction of irrigation projects under the 1902 reclamation act, provision was made for the acquirement of water rights for such federal projects in accordance with the laws of the states in which the projects were located. A similar practice has generally been followed by other federal agencies requiring water rights for their projects.

In recent years attempts have been made to secure court decisions recognizing that the federal government can proceed independently of state governments in acquiring water rights to the unappropriated waters of the western states. To date these attempts have not been extended to interference with rights already acquired under state law. With the increased extent and variety of federal activity in water matters, the question of who controls the use of water within a state has become a vital matter in any state system of acquirement of rights. A permit under state procedure will have only limited value if its terms are not binding on federal uses.

The current differences in this field result mainly from the position taken by the federal Department of Justice rather than from action by the federal administrative agencies dealing with water or from legislation by Congress. Various statutes recognizing the state's right to administer water rights within its area appear to express the intentions of Congress adequately. Court decisions to date have been based on the particular conditions of each case and have not defined the basis to be used in all cases.

The federal activities in this field appear to result from the desires of advocates of increased centralization of government to transfer water titles to federal control. The western states have proceeded too far with their development for such a change to be made without major disturbance of both their present and future development. The issues involved are too complex to be more than mentioned here. California should attempt, by all available means, to retain control of the waters within the state and to preserve her interest in all interstate streams.

Changing Standards in Water Rights

The preceding discussion has traced the establishment of the basic principles relating to rights in both surface and ground waters together with the policies and practices governing their acquirement and administration. Out of the experience of the first hundred years of statehood, California had developed a workable water-right system under which those using water could determine the security of their title to their use and those planning projects to use unappropriated water could predict, with reasonable certainty, the water which might be available for their use. As development proceeded, conditions became more complex as more rights were acquired on the streams and the remaining unappropriated water became more infrequent in its occurrence. However, the basic system of title had become relatively stable. Under these conditions California had made an outstanding development of its water resources under local initiative and financing.

It would seem that the principles of water rights that had been developed over the history of the state and had been found to be equitable in protecting both public and private interests would also be equally suitable for use by the state for projects which it might construct. The state should be willing and able, when it becomes an appropriator of water, to comply with the same rules it requires other appropriators to meet. Such an expectation has not been realized. The Legislature has exempted the state, in its own projects, from the requirements of diligence applicable to other appropriators. It has also provided that where state appropriations of water have been made, the state and any other appropriators receiving assignments or releases under state filings are subject to reservations in favor of the areas of origin to which other appropriations are not subject.

As a result of these changes, much of the procedure under the Water Commission Act has been replaced by procedure under the Department of Water Resources. Where securing a permit was formerly a matter of compliance with the rules of the then Division of Water Rights, it is now a matter of securing discretionary permission of both the present California Water Commission and the Water Rights Board.

These changes in the basis of water rights have not been before the higher courts for a definition of their limitations. Statutes cannot create exemptions from the general constitutional requirement of reasonableness for all uses. A reservation for an area of origin which resulted in an unreasonable use of water would presumably be invalid. It is to be expected that some standard of reasonableness will also be applied to the avoidance of diligence.

The statutes relating to reservations for areas of origin were enacted without repealing other provisions of the Water Commission Act with which they might be in conflict. It has only equal standing in the present water code, with the statute recognizing preferences in acquiring water for municipal use. The question of which provision will govern when an application to export water for municipal use conflicts with an attempted reservation for an area of origin remains to be determined.

Within the general constitutional requirements of reasonableness, the Legislature has authority to define the standards of diligence. For state applications the past standards have been very liberal. As a practical matter the State Water Rights Board cannot consistently enforce a more severe standard of diligence on projects of others than the state has adopted for its own projects. The state is a single overall agency and consistency in the actions of its different parts is a requirement of orderly progress.

Future projects will become more extensive and complex. This is a necessary result of the complete use of local supplies and the need to seek more

distant sources. Such future projects will require larger forms of organization for their construction than have been needed in the past. Present plans are being made on the basis of state or federal construction. Some adjustments of past water-right practices will be needed to meet the conditions of such projects. It is hoped that such changes will be based on the water-right principles that have been found to be effective in the past without attempting to establish lowered standards of diligence or of reasonableness of use in areas of origin.

CHAPTER IV

Use of Water in Mining

The earliest mining in California was by individuals or small groups using hand methods. Washing of the sands was required but only limited amounts of water were needed. Soon the extent of the mining operations required the diversion of water out of the stream channels to permit access to the stream-bed gravels and conveyance to off-channel gravel areas.

The working of surface deposits for gold proceeded from the miner's pan to the cradle, the Long Tom, the riffle box or sluice, the ground sluice, booming or gouging and finally to hydraulic mining. Each of these methods required the use of increasingly larger amounts of water.

The Miner's Inch

Among the water terms used in early mining practice is the miner's inch. This unit of water measurement came into general use where water was sold for mining purposes. A simple method where rates of flow of water could be measured in linear dimensions was needed. This need was met by the use of a rectangular area of flow operating under a constant pressure or head. By using a constant pressure, the discharge could be determined from the area of the

opening in square inches and the pressure, in inches on the center of the opening. The flow through each square inch of area of such an orifice opening was a miner's inch. This term came into wide use in mining and has been carried forward into use in present irrigation practice, although different types of measuring structures are now generally used.

In using the miner's-inch box it was more convenient to adopt some even number of inches for the pressure and practice settled principally on values of either four or six inches. These differences still exist and it is necessary to know which value is being used before a rate of flow represented by some number of miner's inches can be converted into other units. The unit now more generally used for a rate of flow is the cubic foot per second, frequently shortened to second-feet. This is the quantity of water passing a given point each second if the area of flow is one square foot and the velocity one foot per second. For a six-inch pressure on a miner's orifice, forty square inches of opening are required for a discharge of one second-foot; for a pressure of four inches, the corresponding area is fifty square inches. To avoid confusion where the term miner's inch was used without defining the pressure, the Legislature in 1872 adopted the four-inch pressure. This was changed in 1901 to define the miner's inch as one and one-half cubic feet per minute, which requires a six-inch pressure. Several other variations in the measuring structure have been used in some local areas. The statutory miner's inch in California is now one-fortieth of a second-foot, although the more widely used value, particularly in southern California, is one-fiftieth of a second-foot. While convenient for use in measuring small flows, the term miner's inch should not be used in definitions of water rights or water supplies unless the value intended is also expressed in some nonvariable unit, such as second-feet or gallons per minute.

Early Mining Ditches

All water projects for mining were not profitable. Most of the earlier and smaller systems serving areas easily reached near the streams found a ready sale for water at remunerative rates. On some of the more expensive systems the returns were not sufficient to meet the costs. The later larger projects were generally more carefully planned, both in their own construction and in the determination of the ground available for hydraulic mining. These were generally successful until this form of mining was enjoined by the courts.

The Tuolumne County Water Company was organized in June 1851 and located a ditch from the South Fork of Stanislaus River to Columbia. Columbia was an area of rich gravels but lacked adequate local water supplies to operate more than 50 "tom" streams even when used and reused. This company had twenty-one members who subscribed for stock and worked on the ditch and others who invested cash. It had its own sawmill to produce the lumber needed, using boilers secured by dismantling the steamboat "North Star." By May 1851, two hundred to three hundred "tom" streams could be delivered to Columbia with branches to other adjacent areas. Two reservoirs stored water for low-water use.

This company charged $6.00 per "tom" stream per day. The miners considered these rates too high and their reactions were similar to those shown by present-day public utility consumers under similar conditions. The company was asked to cut their rates to $4.00 per day. The company expressed its intention to reduce its rates as soon as it could be done without too great a loss to the company but declined to make an immediate reduction, as it was then only earning 2 percent per month on its actual costs for the system. This refusal was followed by a miners' meeting at which a resolution was passed condemning the company. This resolution includes the following declarations.

"Whereas - The miners of this community have for a long time been oppressed by the exorbitant exactions of that monster monoply, the Tuolumne County Water Company, whose controlling spirits have been fattened by the sweat of the brow of the care-worn working man.

"and whereas - We have in vain appealed to them on various occasions for a reduction in the price of water, without a hope or prospect of success from that corporation, which is without a body to be kicked or a soul to be damned, and whose cupidity knows no bounds.

"and whereas - A vast majority of the claims pay so poorly that many of us cannot pay the honest demands of merchants, boarding house keepers, and others, and as many of us are reduced to nearly a starving point, and have families at home in equally as bad condition."

Three days later another mass meeting was held at Sonora, reportedly attended by 5,000 miners. The miners stopped taking water and the water company found its business at a standstill. A competing ditch was later built which was completed in 1858; its completion being celebrated at Columbia with a claimed attendance of 40,000 people from all parts of the county. This Columbia and Stanislaus River Water Company operated until 1860, when it was purchased by the Tuolumne County Water Company.

This record indicates that the present generation has not improved on the virility of expression of the early miners and that the outcome was not essentially different from present results.

Hydraulic Mining

Hydraulic mining is the process of breaking and washing the deposits of gold-bearing material by the use of water under pressure. The gravel banks were undercut and sluiced by the force of streams of water discharged through nozzles with velocities similar to those now used in fire-fighting equipment.

The conditions for successful hydraulic mining are well described in the following quotation from a report of the State Mineralogist for 1880-82 on Placer, Hydraulic and Drift Mining: "Hydraulic mining is the outgrowth of the already described modes of placer mining. It is the application of natural forces to move large quantities of earthy matter, and the collection of a certain quantity of gold so small as not to admit of its being profitably saved by any of the earlier methods. To be successful, certain conditions must exist, which can only be found in a newly settled mountainous country. These conditions are as follows: An abundant supply of water, which must be free, or which can be purchased cheaply; a deposit of loose easily disintegrated earth, which contains gold in sufficient quantity to pay for working; bedrock not too deep below the surface; a channel into which the debris can be discharged; high ground above the claims, to which the water can be conveyed to give the required pressure."

These conditions adapted to hydraulic mining were found in California. Hydraulic mining was extensively and successfully practiced until California ceased to be a "newly settled mountainous country" and conflicts arose over the effect of the mining debris on the lower valley lands.

Gravels containing less than 15 cents of gold per cubic yard could be worked profitably by hydraulic mining. It is reported that 43,000,000 cubic yards of easily moved gravel at Gold River were mined prior to 1874 which had a yield of only about five cents per cubic yard. A bank 45 feet high would have a gross yield of about $5,000 per acre if only seven cents per cubic yard were secured.

Watkins photograph from Bancroft Library

Hydraulic Giants at Work

From U.S. Geological Survey, Professional Paper 105

Deposit of Hydraulic Mine Tailings in Deer Creek, Nevada County

In the earlier practice the hydraulic nozzles were used to cut into the gravel banks until the cut exceeded 300 feet in depth; caving of such banks with injury to the crew sometimes resulted. Later practice used cuts of less than 150 feet with the deeper banks being taken out in benches. Performance was generally measured in terms of the number of cubic yards of gravel moved per miner's inch of water used per day. This duty, as it was called, usually varied from one to four cubic yards. A duty of three cubic yards per twenty-four-hour inch represents about 4 percent of the volume of water used to move the mined material.

Water for hydraulic mining was sold on the basis of the miner's inch delivered, usually for a twenty-four-hour period. Usual prices varied from six to twenty cents per miner's-inch day equivalent to $1.50 to $5 per acre-foot. In 1882 it was estimated that over 300,000 acre-feet were sold for hydraulic mining in California.

The record of gold mining in California includes the successful development of much equipment and engineering methods. All of such efforts were not successful, as indicated by the following quotation in the report of the State Mineralogist for 1880-82.

"Whole chapters might be written on some of the powerful implements and inventions that in the foregoing pages have barely been mentioned, to say nothing of others almost equally deserving that have not even been alluded to; but as we have so overlooked much of the effective enginery that the hydraulic miner has called to his aid, so also has nothing been said of the many novel contrivances and worthless machines with which he has at one time or another been induced to experiment, to the great detriment of his business and the depletion of his pocket."

Water Supply Systems for Hydraulic Mining

The requirements of hydraulic mining and the conditions under which they had to be met led to the construction of water systems in the period from 1855 to 1880 which would be a credit to present engineering practice. When the difficulties in securing materials, the absence of the types of construction equipment now available, and the isolated locations at which these systems were built are considered, the hydraulic-mining water-supply systems represent as outstanding achievements as any that have been accomplished in later years in other lines of water use. The engineers of these systems had to rely on their own resources and ingenuity. How well they succeeded is reflected in the by-products of their success represented by the large amounts of material washed into the mountain streams and eventually carried to the lower valleys.

It was estimated in 1882 that there was an aggregate length of mining ditches in California of nearly 6,000 miles with an additional length of branches of 1,000 miles. The U.S. Army Engineers reported a total investment in hydraulic mining, prior to the injunctions restricting its use, of $100,000,000.

Some of the area where the mining ditches had to be located was too steep for sidehill canals. Flumes were hung on cliffs in such locations. The Miocene flume on the West Branch of Feather River was supported on brackets set in a vertical cliff where the workmen were lowered 200 feet to drill the bracket holes.

Gulches or other depressions were crossed on wooden flumes supported on trestles made from the locally cut lumber. One early flume at Big Oak Flat had a height of 256 feet; several exceeded 100 feet. Such flumes had a usual life of eight to ten years, due to wind, fire, and decay.

Inverted siphons made of wrought-iron pipe up to thirty inches in diameter were also used. These pipes were durable and the remains of some of these

early lines could be found until recent years. Among the notable engineering works constructed for hydraulic mining was the Cherokee siphon. This is described by Hamilton Smith, Jr., in his classic book on Hydraulics published in 1886. The author, who had been the engineer for some of the most difficult works constructed for mining use, later returned to the East and became distinguished in the field of hydraulic engineering there. His description of the Cherokee siphon is as follows.

"The conduit pipe of the Spring Valley Mining Company at Cherokee, Butte County, California, was laid in the year 1871, and at this time was the most daring work of the kind ever constructed. It is an inverted siphon, having a length of about two and one-half miles, an approximate diameter of 30 inches, and has a maximum depression of 887 feet below the hydraulic-grade line. It is made of double riveted sheet iron, which is subjected to a constant maximum tensile strain of 17,549 pounds per square inch."

The system of which the Cherokee siphon was a part included 100 miles of ditch built at a total cost of $750,000. To dispose of the slickens, 23,000 acres of land in the adjacent valley were acquired and 40 miles of levee built at a cost of $582,000. Sixteen giants with five- to eight-inch diameters, having a total water supply of about 30 second-feet, were used. During a twelve-year period, work was stopped only once; this stoppage was during the funeral of President Garfield. The mine workings were illuminated by electric light; this was one of the first uses of electricity for this purpose.

Another notable pipeline was that of the North Bloomfield Gravel Mining Company across the Big Canyon branch of the South Yuba River. Built in 1878, this had a maximum pressure head of 760 feet and a length of 4,440 feet. Its diameter was about 17 inches and its capacity 32 second-feet. For this size and capacity the loss of head in friction was about 300 feet. The siphon was equipped with 14 air valves. It had two breaks in its first year of use but operated successfully thereafter.

Storage of Water for Hydraulic Mining

Direct stream flow, even from the higher Sierra streams, is deficient in the late summer, so that the miners needed storage for full-season operation. Several reservoirs for mining use were built. The North Bloomfield system had several reservoirs with an aggregate capacity of 23,000 acre-feet. The main storage was at Bowman Lake; the dam there has been rebuilt and enlarged by the Nevada Irrigation District. The Eureka Lake and Yuba Canal Company had several reservoirs formed by dams at the outlets of small lakes which had a total capacity of about 19,000 acre-feet. The Milton Company and the South Yuba Company also had storage. The latter company's reservoirs at Meadow Lake and at Fordyce Valley are still in use for power purposes. The storage constructed for hydraulic mining had a total capacity of about 150,000 acre-feet.

Effect of Mining Debris

The large volumes of hydraulic-mining debris which were discharged into the stream channels were subject to erosion and movement downstream to the Sacramento Valley. The mining debris began to reach the lower agricultural lands on the Yuba River in 1858. The floods of the winter of 1861-62 moved enough debris onto lands near the Yuba, Feather, and Bear rivers so that the construction of levees was undertaken. Later court actions were started to stop the debris at its source. In 1880 the State Engineer found that 43,546 acres of agricultural land in the Sacramento Valley had been depreciated $2,597,634. The Chief Engineer of the U.S. Army in 1891 found that 39,214 acres had been

destroyed and 13,955 acres injured on these streams with a total loss of $3,294,035.

In 1879 it was reported that 53,000,000 cubic yards per year were being washed into the streams in the mining area. G. K. Gilbert (U.S. Geological Survey, Professional Paper 105) has estimated that the total volume of gravels mined from 1849 to 1909 was 1,555,000,000 cubic yards. To 1879 the State Engineer reported that the low-water plane of the Sacramento River had been raised one and one-half to two and one-half feet at the head of Grand Island, five to five and one-half feet at Sacramento, three to four feet at the mouth of Feather River, and one to one and one-half feet at Knights Landing. By 1890 there had been an additional rise of two feet at Sacramento. To 1879 the similar rise on the Feather River had been three to four feet at Nicolaus, thirteen to fifteen feet at the mouth of Yuba River, and five to six feet at Oroville. In 1849 the tidal range at Sacramento was fully two feet; by 1879 tidal action there had practically ceased. Shoaling had occurred at Mare Island and continued after hydraulic mining was stopped as the eroded materials were transported downstream. It was from 1909 to 1913 before the average low-water reading at Sacramento had lowered to about the elevation in the early 1870's.

The damage done in the lower valley by mining debris resulted in a sharp division between the agricultural and mining interests of the state. Restraining dams were constructed but the types then built had only a limited effect. On the Yuba River about 85,000 feet of levees were built, partly by gold dredgers and partly by the United States. These have held back material that would have moved on to the lower channels. A barrier on Yuba River built in the edge of the valley to store mining debris failed in the flood of March 1907 and has not been rebuilt.

When these early efforts did not prove to be effective, antidebris associations were formed and federal and state investigations were made. In 1881 Governor Perkins sent a special message to the Legislature on this subject. Litigation was brought in both the federal and the state courts. Some relief was secured in the state courts but the decisive case was Woodruff vs. North Bloomfield Gravel Mining Company (18 Fed. 753). This decision by Judge Sawyer in 1884, generally referred to as the Sawyer decision, enjoined hydraulics mining except where it could be operated without discharging the resulting debris into stream channels. The principal legal grounds for this decision was the damage to navigation resulting from the deposit of the mining debris in the navigable channels. The Sawyer decision and its resulting injunction against hydraulic mining applies only to areas tributary to the Sacramento River. Mining on other streams where navigation may not be involved was not affected. Some such mining has continued on the Trinity River and other similar streams.

The trials in the hydraulic mining cases were lengthy and bitter. Each side felt that they were contending for their existence. In one of the early cases, known as the Gold Run case, there were 12,549 pages of testimony, several thousand pages of exhibits, and nearly 1,000 pages of arguments by counsel. One map used was 100 feet long and the physical exhibits would have made a cartload. Even when compared with some of the more recent water cases in California, the Gold Run case represents a lengthy and voluminous record.

Hydraulic Mining after the Sawyer Decision

In an effort to permit hydraulic mining to continue without damage to the valley areas, Congress created the California Debris Commission in 1893 by what is generally referred to as the Caminetti Act. This commission was

Watkins photograph from Bancroft Library

Early Bowman Lake and Dam Used for Water Supply for Hydraulic Mining

Watkins photograph from Bancroft Library

Golden Gate and Golden Feather Mining Claims
on Feather River in Butte County

authorized to grant licenses for hydraulic mining to applicants who could show that they could operate under conditions that would not result in injury to others. The act prohibited hydraulic mining except where such licenses had been secured. To 1944 over 1,200 applications for such licenses had been made but only 23 operations had been licensed. Only limited amounts of hydraulic mining are feasible under this act, as the means of restraining the debris which are required for large-scale operations are generally too costly.

Under the California Debris Commission Act, storage could be constructed for the purpose of storing mining debris, with those using such storage charged for the use of the storage space they filled. The permissible charges were limited to 3 percent of the gross returns of the mining operations using such storage. These charges were not sufficient to make the construction of such dams attractive as private investments. No such dams were built for forty years after the passage of this act.

There was a revival in the interest in hydraulic mining during the 1930's. In 1935 Congress authorized the construction of four dams and appropriated funds for their construction. The Upper Narrows Dam on Yuba River and the North Fork Dam on the North Fork of American River were built. At the Upper Narrows Dam, storage charges for mining debris were set at 2.30 cents per cubic yard; power is also produced at this dam and assists in meeting its cost. The storage charge at the North Fork Dam was set at 3.11 cents per cubic yard. The other two dams authorized have not been constructed.

Costs of debris storage and uncertainties regarding its effectiveness are deterrents to extensive mining. While debris storage can prevent the movement of sands and gravels to the valley areas, users of water for domestic and power purposes demand water relatively free of fine silt and even of turbidity. Methods to meet these requirements at practical cost have not, as yet, come into use. The present low price for gold in relation to the costs of operation is also a factor in hydraulic mining, as it is in all forms of gold mining.

While there is continued interest in the mining of the large remaining values in the available gravels of the Sierras, extensive revival of hydraulic mining does not appear to be probable under the existing conditions. The water supplies formerly used for hydraulic mining are now largely in use for power and irrigation at locations below the elevations of the main gravel areas.

Gold Dredging

Gold dredging consists in excavating the gold-bearing gravels in place, extracting their gold, and piling the washed gravels in the pit from which they have been excavated. As the mining debris is not discharged into the streams, such dredging does not violate the Sawyer decision or the terms of the California Debris Act. Such dredging had been undertaken as early as in the 1850's near Oroville, but large-scale operations had to wait for the development of machinery capable of handling large volumes of material at costs within the value of the gold obtained. As most of the deposits available for dredging have gold values of ten to twenty cents per cubic yard, costs of dredging must be low for profitable operation.

The requirements for successful dredging were listed in 1905 in Bulletin 36 of the California State Mining Bureau. These are still applicable. There must be loose gravel free from clay and large boulders, a soft bedrock in which the dredgers can dig to secure the bottom gold, and fine gold which amalgamates easily. These conditions occur in the gravels along some of the Sierra streams where they enter the valley. In higher areas the boulders may be too large or the bedrock too hard.

Gold dredging has a limited water requirement. The dredges float in the ex-

cavation which they make. As much of the dredged areas are low lands adjacent to streams, ground water may supply the water needed. Delivery of water to maintain the dredge pool has been needed in some cases. Only one to two second-feet of water may be needed for washing the gravel; this can be secured from the pool and returned to the pool after use.

Modern gold dredges may handle 300,000 cubic yards of material per month at costs of five to six cents per cubic yard. The dredge buckets may have capacities as large as ten cubic feet and the dredges may be capable of digging to depths of 90 feet.

The largest gold-dredging areas in California are along the Feather River below Oroville and the American River below Folsom. It has been estimated that there is a total area suitable for dredging of about 25,000 acres. As some of the potential dredging areas are also adapted to agriculture, there has been controversy over the dredging of such areas. In dredging, the material is reversed in position and the surface-soil materials are replaced by the gravel and cobbles from the greater depths. The dredged material may be left in irregular piles, making cultivation impractical. Some dredged areas have been relevelled with trees planted in soil-filled pockets in the gravel. Some dredged land can be used for industrial and residential purposes. Such uses to date represent a small part of the areas which have been dredged.

From time to time efforts have been made to restrict dredging by legislation. As dredging does not interfere with navigation, federal interests have not been involved and such legislation would be by state statute or county ordinance. To date restrictive state legislation has not been passed. County ordinances have been enacted in some counties; their constitutionality has not as yet been fully tested.

Regulation of gold dredging would be an exercise of the police power. Such dredging does not injure others, create public nuisances, or menace public health. Opposition to dredging rests primarily on the destruction of an agricultural asset. As the lands dredged are in private ownership, the earlier concepts of property rights furnish only limited support for the prohibition or restraint of dredging. The gold content of the dredged lands has had values several times the value of the dredged areas for agricultural purposes. The outcome of the conflict over limitations on dredging will furnish an illustration of the balancing of the rights of owners of land to use it for its most profitable purpose and the general public interest in the preservation of the agricultural assets of the state.

CHAPTER V

Navigation

As a coastal state, California has always made extensive use of ocean transportation. The water used for such navigation is not affected by the development of the internal water supply of the state. Improvements have been made in the coastal harbors and their use can be expected to continue to expand.

Navigation of inland waters may result in conflicts with the use of water for other purposes. In the use of the water supply for over-all maximum benefits, inland navigation should be given consideration on the basis of its total usefulness in relation to the usefulness of water for other purposes. This is, in general, being done and such navigation is taking its appropriate place in the economy of the state. Present inland navigation in California is confined mainly to the Delta of the Sacramento and the San Joaquin rivers. There is some use of additional portions of these streams and there are also navigable lakes such as Lake Tahoe. Navigation of the Colorado River has ceased.

Control over navigation was assigned to the federal government by the states in their adoption of the federal constitution and has remained a federal function. In the earlier development of the United States, inland and coastal navigation was an important means of transportation. Navigable streams determined the

location of much of the early settlement. Railroads, highways, and use of the air have reduced the dependence on navigation. Notwithstanding these changes in the economics of transportation, the legal control of the federal government of navigation has been used by the federal courts to support and expand federal control of the use of water for other purposes.

The federal functions relating to navigation are administered by the Corps of Engineers, U.S. Army. These functions include construction of works for the improvement of navigation, supervision of other works which may affect navigation, reports on proposed projects and estimates of their economic feasibility, and the fixing of pier spacing and heights of clearance for bridges over navigable waters.

Prior to 1944 the U.S. Army Engineers had jurisdiction to prevent diversions from streams which would affect their navigability. This jurisdiction had not been enforced to prevent irrigation development. When diversions from the Sacramento River reduced the flow so that it was not navigable above Sacramento, warnings were issued that diversions might be restricted but no direct action was taken. Foreseeing that such restrictions might be enforced, the Sacramento Valley Irrigation Company (predecessor to the Glenn Colusa Irrigation District) secured an act of Congress in 1906 recognizing its right to divert nine hundred second-feet.

To meet possible future conflicts, the western states secured a provision in the 1944 flood-control act limiting the use of water for navigation in the states wholly or partly west of the ninety-eighth meridian to use that does not conflict with any present or future beneficial use for other purposes.

Lands underlying navigable waters are the property of the state. The states have jurisdiction to protect their ownership of such lands. States may construct and operate works related to navigation; California has built and operates the docks of San Francisco harbor. The states may also regulate intrastate commerce on navigable waters.

Plans for some early irrigation canals in California included their use for navigation. The survey made by the state in 1866 for a canal on the west side of the Sacramento Valley included navigation in its purposes. A favorite early plan was a canal along the west side of the San Joaquin Valley from Tulare Lake to Antioch. The San Joaquin and Kings River Canal, diverting at Mendota, made an unsuccessful effort to secure a grant of alternate sections of public land along its course similar to the grants then being given to railroads extending transportation into new areas.

In the seventy years prior to 1945 the federal government spent over $13,000,000 on the improvement of navigation in the Sacramento and the San Joaquin valleys and in their connecting delta. Of this $4,700,000 was spent on the thirty-foot channel to Stockton; local interest also contributed $1,300,000 toward this project.

Preliminary plans for the comprehensive development of the Central Valley were announced in 1945 by both the Corps of Engineers and the Bureau of Reclamation. Neither of these plans recommended navigation facilities in addition to those then authorized. The navigable depths of the Sacramento River would not be increased over those to be made available by the present Central Valley Project. Plans for irrigation in the San Joaquin Valley would leave no stream flow available for maintaining navigable depth and no plans were proposed for slack-water service. Navigation will continue to be available within the tidal areas of these valleys and by constructed ship channels to Stockton and Sacramento.

Navigation on Sacramento River

The first reported navigation into the Delta was in 1811 by boats rowing from the Presidio of San Francisco to Suisun Bay and into the Delta. Some early sailboats used the wind and tide to reach the Delta channels. Where the trees along the channels shut off the wind, warping was sometimes used. This consisted of carrying a line ahead, fastening it to a tree, and hauling up the boat by hand. Three miles per day could be made. Nearer Sacramento, the channels were wider and sails could be used. Such trips from San Francisco to Sacramento might take fifteen days. The first steamboat to reach Sacramento was the "Sitka" in 1847.

The steamer "McKim" was brought from New Orleans in September 1849 and placed on the river run to Sacramento. On its first trip the fare was $30. In later years competition was severe and at times passengers were carried at nominal rates during rate wars between rival boats.

From 1850 to 1863 seagoing vessels up to thirteen-foot draft could always reach Sacramento and light-draft vessels went on to Red Bluff. In later years mining debris reduced the channel so that boats with six-foot draft could not reach Sacramento during late summer months.

The best length for boats on the Sacramento River was found to be about 175 feet. Longer boats encountered difficulties at some of the sharper river bends. Barges carrying 600 to 700 tons reached Colusa; above Colusa not over 300-ton cargoes were attempted.

A feature of the steamboat traffic to Sacramento was the racing between rival boats. The "Chrysopolis," built in 1860, made a trip from San Francisco in five hours and nineteen minutes; this boat remained in use on San Francisco Bay as a ferry until 1940. The "New World" made a trip from Sacramento to San Francisco in five hours and forty-six minutes. Some of these races resulted in overloaded boilers and explosions. The largest disaster was the explosion on the "Pearl." This occurred near the mouth of the American River on January 27, 1855. Of the 100 people on board, 67 were killed.

The last of the finer boats were the "Delta King" and the "Delta Queen," built in 1926. The overnight run between San Francisco and Sacramento was a popular means of travel between these two cities. This service continued until November 1941. The "Delta King" was taken to China for use on the Yangtse River. It came back in 1958 and in 1959 was taken to Stockton to be used as a cafe. The "Delta Queen" was leased to the Navy in 1941 and used as a troopship and floating hotel on San Francisco Bay. In 1947 the "Queen" was sold for use on the Ohio River. It was taken there through the Panama Canal and is still in use. Ferry service on San Francisco Bay stopped, except for connections with passenger trains and car ferries, following the completion of the Bay and Golden Gate bridges.

The first federal appropriation for navigation improvement on the Sacramento was made in 1875 for snag removal and for brush dams on the Feather River. The 1879 report mentions a survey by the state of a canal from Gray's Bend, thirty-five miles above Sacramento, to Rio Vista. The existing navigation project for the Sacramento River calls for a ten-foot depth for the sixty miles from the mouth of the river to Sacramento. This was completed in 1931; the largest part of the work required was the dredging of the mouth of the river to remove the restriction there resulting from the silting with mining debris. Above Sacramento the present project calls for a six-foot depth for eighty-five miles to Colusa, five feet for the next fifty miles to Chico Landing, and such depths as may be practicable for the remaining fifty-two miles to Red Bluff.

In recent years the release of storage from Shasta Reservoir for use by the

Central Valley Project has resulted in the maintenance of a minimum flow of 5,000 second-feet, except for infrequent deficiencies, in the Sacramento River near Knights Landing. This flow is expected to permit the maintenance of navigable depths of six feet to Colusa and five feet to Chico Landing.

Studies of the U.S. Army Engineers and of the state resulted in estimates that the improvement of the Sacramento River above Sacramento consisting of channel work with the storage releases from Shasta Reservoir would develop a water traffic of 1,320,000 tons per year with a saving in transportation costs of $1,650,000 annually. Deducting the estimated cost of channel maintenance gave a net annual benefit of $1,314,000.

In 1935 Congress authorized the expenditure of $12,000,000 for the benefits to flood control and navigation to result from the Central Valley Project. The act of August 28, 1937, provides that this appropriation shall be expended by the Secretary of the Interior and that it would not be reimbursable from the revenues of the project. This act also provides that the dams and reservoirs of the project shall be used: first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic use; and, third, for power.

In the report on which this appropriation was based, the Corps of Engineers found capitalized direct benefits to navigation of $5,000,000. An additional capitalized benefit of $5,630,000 to navigation resulted from the elimination of a salt-water barrier which would be made possible by the construction of Shasta Dam.

In later studies reported in 1945, made by a joint group representing various interests in the Central Valley Project, the cost allocation recommended to be charged to navigation was $12,454,000 for direct benefits and $5,630,000 for the elimination of a salt-water barrier. The direct benefits consisted in the reduction in transportation costs from the use of the navigable depths the project would make available above Sacramento with small benefits for similar improvements below Sacramento and the longer life of piles in areas to be protected from salt-water intrusion. These recommended allocations to navigation were approved by the President and transmitted to Congress early in 1947.

A ship channel to Sacramento was authorized in 1946 and is under construction. This will have a length of 44 miles from Collinsville to the turning basin at Sacramento. The channel will be 200 to 300 feet wide and have a depth of 30 feet below mean lower low water. Much of the channel will be located along the east levee of Yolo By-pass. The estimated total federal cost is $45,600,000. The city of Sacramento has voted bonds for its share of the costs.

Navigation on the San Joaquin River

Navigation on the San Joaquin River has consisted mainly of service to Stockton, with some irregular early-day use of the river as far as Herndon. Stockton is adjacent to the Delta and is practically at sea level. Diversion from the San Joaquin River for irrigation took a large proportion of the low-water flow at an early date and barge traffic has been limited since the 1870's.

In 1848 the whale boats of Captain C. M. Weber reached Stockton, followed by the small sloop "Maria." Boats abandoned in the channel at Stockton in 1850, when their crews left for the mines, blocked its navigation to an extent that the local merchants petitioned for their removal.

A report resulting from an extensive study of navigation on the San Joaquin River was made by the Corps of Engineers in 1917. From 1860 to 1870 supplies were commonly moved on the river to Herndon or beyond. Navigation above Mendota Dam ended with the extension of the railroad on the east side of the Valley in 1871. However, when the diversion dam at Mendota was rebuilt in

San Francisco Maritime Museum Association photograph

River Boat "Reform" and Sailboats in Sacramento River near Grand Island

U.S. Bureau of Reclamation photograph

Inland Navigation. Barges at Sacramento Docks

1916 a movable section fifty feet long was included for use as a navigable pass at high stages.

This report recognized that the paramount interest in the San Joaquin Valley was in the use of its water supply for irrigation rather than for navigation and that there was not enough water for both uses. It was also found that, to be effective, navigation would require a series of locks and dams for which the costs would exceed the benefits which would result from the probable amount of their use. It was recommended that the United States should not assert its right to maintain navigation to an extent that would interfere with diversions for irrigation. This report commented that an outlet channel for navigation from Tulare Lake to the San Joaquin River, which had been suggested, was "entirely impracticable."

The existing project on the San Joaquin River to Stockton has a depth of thirty feet with a turning basin at Stockton. The Port of Stockton is municipally owned; it includes public wharves and a belt railroad. Local interests contributed about one-fourth of the total channel costs of $5,000,000.

Navigation on Colorado River

In 1540 Vasquez de Coronada, exploring in New Mexico, sent Dias to the west. He discovered the Colorado River and followed it to its mouth. About the same time Captain Fernando Alarcon sailed up the Gulf of California and continued up the river to near the present town of Blythe.

Fort Yuma was established in 1850 to aid in the control of the Indians in its vicinity. In 1851 Lieutenant George H. Derby was sent from San Francisco with a schooner to survey a navigable route by which Fort Yuma could be supplied. The first steamboat operating on the river was the "George A. Johnson," which took provisions to Yuma in 1852. Seagoing boats transferred their cargoes to river boats at the mouth of the river.

The tidal action at the mouth of the Colorado causes a tidal bore. With the large tidal range at the mouth, the bore may reach a height of several feet in constricted portions of the river channel. Travel up the river was limited to the flood tide. At nights the boats tied up, as sand bars made night travel precarious.

In 1857 the Army had an iron steamer, fifty feet long, constructed in sections in Philadelphia, shipped to Panama, taken across the Isthmus, and shipped to San Francisco. It was then shipped back to Robinson's Landing and put together there, starting up the river under its own power in January 1858. This boat, called the "Explorer," proceeded to Yuma under the command of Lieutenant Joseph C. Ives. As the river was at a low stage, many bars were encountered over which the boat was worked. To avoid these and to cut wood for fuel, it was tied to the bank each night. The "Explorer" proceeded above Yuma and, after many difficulties, reach Black Canyon. A further trip of thirty miles was made into Black Canyon in a skiff. This represents the farthest navigation up the Colorado from its mouth. The "Explorer" started back on March 12, 1858, and reached Fort Yuma without accident. Its abandoned hull was found on the Colorado River delta in 1930.

Navigation continued on the Colorado, both above and below Yuma, until the completion of the railroad to Yuma in 1877. Navigation below Yuma ended with the coming of the railroad but boats continued to be used to supply interior points up the river. Occasionally during this period boats reached Callville, which is above the present site of Hoover Dam. These river boats had drafts of about two feet. In 1907 the completion of Laguna Dam, a few miles above Yuma, stopped any further navigation on the river.

The navigability of the Colorado River was an issue in the suit brought

by Arizona to enjoin the construction of Hoover Dam (Ariz. vs. Calif. 283 U.S. 423). The U.S. Supreme Court decided in 1931 that the Colorado River had been navigable in fact and had continued to be navigable in law. Being navigable, the construction of a dam to regulate its flow was held to be an aid to navigation and a proper expenditure of federal funds.

Navigation of Lakes

Several lakes in California have been used for commercial navigation. Their present use is mainly for pleasure boating. Use of their inflow has resulted in the depletion of Tulare and Goose lakes, except during periods of excessive runoff.

On Lake Tahoe the earliest reported navigation was a trip around the lake in a rowboat in 1856 by A. H. Hawley and two others. Mining on the Comstock required large supplies of mine timbers. Much of this came from the area around Lake Tahoe in both California and Nevada. The logs were rafted across the lake, transported to the crest of the mountains by team or railway, and conveyed to the Carson Valley by a log flume. The largest boat used to tow logs was the "Meteor," which operated for this use from 1876 to 1896 and as a passenger and mail boat until 1928. In 1939 the "Meteor" was sunk in deep water in recognition of her long service and to avoid the ignominy of being sold for scrap. Over the years many boats of various sizes and types were used. Daily mail and express boat service ended in 1943 when improved highways around the lake resulted in their use for mail and freight. Navigation on Lake Tahoe is now limited to pleasure craft.

Prior to the diversion of much of its inflow and the reclamation of its area, Tulare Lake was used for local navigation. Fishing was active in the 1870's and 1880's, with reports of catches of as much as a ton and a half with single drafts of the seines then used. Tulare Lake was also the source used to supply terrapin for the San Francisco market. During the flood of 1862, an attempt was made to run a stern wheeler from the San Joaquin River to Tulare Lake. It grounded and was left stranded; for many years the hull and wheel were on the dry plains where it was left. In 1868 a scow, which was loaded in the lake, took a ton of honey through Tulare and Summit lakes to Fresno Slough and on to the San Joaquin River. This is the only record of navigation from Tulare Lake to tidewater.

Goose Lake, like Lake Tahoe, is an interstate lake. In sequences of years of large runoff, Goose Lake has filled and spilled briefly to the Pit River. Use of its inflow for irrigation now results in lower stages; the lake was generally dry from 1925 to 1934. From 1880 to 1910 it was at generally high stages. When the railroad was built to Alturas about 1910, passengers and freight were carried the length of Goose Lake by boat. The extension of the railroad to Lakeview and the construction of an improved highway ended this navigation before the lake went dry.

Clear Lake is a generally shallow lake about twenty miles long. Its elevation fluctuates over a limited range. Its outlet to Cache Creek is over a broad ridge which restricts the outflow. There has been sufficient use of the lake for some local transportation and for pleasure craft for it to be legally navigable.

Lumber Flumes

Lumber flumes are a form of transportation, not generally classified as navigation but using water to move a commercial product. These flumes were triangular in section and were used to transport logs and lumber from their points of origin to their place of use. They were extensively used in Califor-

nia in the earlier years of lumbering when other forms of transportation from the timbered mountain areas to the valley markets were less economical than at present. All lumber flumes were privately built and operated. They served a useful purpose but have been replaced by railways or trucks.

As early as 1851 there was a water-power sawmill on the Sacramento River just above the mouth of Mill Creek. The logs it cut were floated down the Sacramento River from Shasta. In 1875 there was a flume from Battle Creek to Sesma on the Sacramento River and one from Chico Creek to Chico. The latter was thirty-eight miles long and included flumes eighty to one hundred feet high and handled fifty to one hundred thousand board feet of lumber per day. The flume of the Madera Lumber Company was in operation from 1876 until 1935. It brought lumber fifty-two miles from two mills on the headwaters of Fresno River and the North Fork of the San Joaquin River. It is reported to have had a capacity of fifty to seventy-five thousand board feet per day and to have cost $460,000.

The Kings River Lumber Company had a flume which, with its laterals, had a length of sixty miles and a capacity of two hundred fifty thousand board feet per day. The earlier mill was at Millwood and the flume ended at Sanger. Later this property was sold to Hume Bennett and the mill moved to Hume with the flume used to move its output.

The Fresno Flume and Lumber Company flume brought lumber from Shaver Lake to Clovis. Tow steamers were operated on Shaver Lake. This flume was forty-five miles long. Construction on both the dam at Shaver Lake and the flume began in 1892; the flume was in operation in 1893.

California Seaports

The California seaports have a large traffic. The development and use of the runoff of California streams will not affect the water available for these seaports and their traffic is outside the scope of this discussion. Los Angeles and San Francisco Bay are the largest ports. San Diego, Long Beach, and San Luis Obispo have substantial amounts of shipping, with Monterey Bay, Humboldt Bay, and Crescent City serving as outlets for their local areas. Prior to the construction of the Bay Bridge, ferry traffic to and from San Francisco represented about 35,000,000 passengers per year. A channel thirty feet deep is maintained to the Mare Island Navy Yard at Vallejo.

CHAPTER VI

Irrigation

It is difficult to present a connected history of irrigation development in a state as large and as diverse as California. If a strictly chronological treatment is used for the whole state, the continuity of development in different areas is interrupted. If each area is discussed separately for its full history, general conditions affecting the whole state are omitted. An intermediate form of presentation has been used in the following discussion. The earlier history is described on a general basis until the state reached an extent of development in which individual areas and projects justify description. The discussion of local areas is carried forward until the development reaches the point where coordinated projects for multiple uses have been studied or undertaken. These comprehensive projects are later discussed in a chapter of their own. While this form of presentation has some complications, it is thought that it is easier for the reader to follow than other forms that might have been used.

General History

The original conditions and the irrigation in California in 1848 have been described in earlier chapters. There had been so little development at that time

that practically all of the present irrigation has been accomplished in the last one hundred years.

Irrigation in California has proceeded on both a statewide and a local basis. All parts of the state are subjected to the same general economic conditions and move ahead or retard their rate of development at similar times. Both northern and southern California felt the effect of the increased demand for land in the "land boom" of the 1880's, which was followed by the depression of the early 1890's. Different parts of the state may also have their own local rates of irrigation development, depending on such factors as special demands for certain crops or the construction of some large project bringing in new acreage.

By 1870 there were about 60,000 acres irrigated in California. There were small diversions from the streams in southern California and some irrigation from mining ditches. There were some diversions onto adjacent bottom lands from streams in the southern San Joaquin Valley and from Cache Creek.

The first report and the first plan which can be described as "comprehensive" for the Central Valley was made by a federal commission in 1874. These results are generally known as the Alexander report. A general outline for the development of the Central Valley was presented with comments on the policies which should be followed. This report is discussed in chapter XII.

While irrigation development proceeded slowly in the early years of statehood, it was a matter of state interest. This is shown by the legislation passed from time to time providing for investigations and forms of organization for irrigation development.

The early interest of the state in its water resources is indicated by the act approved March 29, 1878, creating the office of State Engineer. Section 3 of this act is as follows:

"The duty of the State Engineer shall be, under the direction of the Governor, to investigate the problems of irrigation of the plains, the condition and capacity of the great drainage lines of the State, and the improvement of the navigation of rivers."

Following the passage of the 1878 act, William Ham Hall was appointed State Engineer and he organized a staff to carry out his duties. This staff included James D. Schuyler, Marsden Manson, C. E. Grunsky—who later became leading engineers in the development of the water resources of the state.

In 1880 the State Engineer reported that the total area irrigated in the parts of the state for which he had information was 292,885 acres. This consisted of 82,485 acres in San Bernardino and Los Angeles counties, 188,000 acres in the San Joaquin Valley, 13,400 acres in the Sacramento Valley on Cache Creek, and 9,000 acres in the Sierra foothills. These figures were based on investigations by the State Engineer and should be reasonably accurate for the areas covered. Similar figures are not available for the other areas in the state, such as the Delta and overflow lands of the Central Valley or the coastal valleys north of Los Angeles County. With allowance for such areas, it is probable that the total area irrigated in California in 1880 was less then 400,000 acres.

In 1889 the first federal census of irrigation reported 1,004,000 acres irrigated in California. The similar result in 1899 was 1,445,000 acres. A special federal census in 1902 found the irrigated area had increased to 2,644,000 acres and by 1919 to 4,220,000 acres. From 1919 to 1929 the increase in irrigated area was only about 500,000 acres; although this was a period of active financing and construction, the new projects had not been completed to serve large new areas. In 1939 the increase from 1929 was 323,000 acres, giving a total area in the latter year of 5,070,000 acres. The census of 1950 reported 6,599,000 acres irrigated in California.

The first use in the San Joaquin Valley of a pump on a well used for irrigation is reported to have been in the late 1880's near Porterville. The first electrically driven plant there was in 1894. The 1940 census reported 52,000 pumping plants used for irrigation in California, having a total rated capacity of 39,000,000 gallons per minute or 87,000 second-feet. The rated capacity of the power used for this pumping was 968,000 horsepower. The average lift was fifty-five feet. If the full rated capacity of this power was used to pump this rated pump capacity with a lift of fifty-five feet, the average over-all efficiency would have been about 54 percent. Fifty-two percent of these pumps were deep-well turbines, 32 percent centrifugal, and the remainder miscellaneous types. Electric power was used for 80 percent of these plants, internal-combustion engines for 12 percent, and the rest were mixed types.

By 1950, 45 percent of the area irrigated in California was reported to be entirely supplied by ground water and an additional 18 percent to be supplied by surface waters supplemented by ground water. These results illustrate the very extensive use that is made of ground water as a source of water supply. They also illustrate the unusually favorable ground-water conditions. In 1950 the number of plants pumping ground water had increased to 79,900, of which over 90 percent used electric power. This increase in the number of plants accounts for the greater part of the increase in irrigated areas from 1940 to 1950. From 1940 to 1950 the average lift increased from fifty-five feet to eighty-eight feet.

The State Division of Water Resources made a survey of the areas irrigated in California in its investigations of the water requirements of the state. This survey extended from 1946 to 1953; the results are generally representative of the extent of irrigation in about 1950. They indicate the extent of present irrigation and its distribution over the state. The following results have been taken from Bulletin 2 on Water Utilization and Requirements of California. The total area irrigated as shown in Bulletin 2 agrees closely with the total area reported by the U.S. Census for 1950.

The irrigated area in California, as classified in Bulletin 2, consists of 44 percent forage-type crops, 20 percent orchard and vines, 14 percent field crops such as beets, beans, and rice, 11 percent truck crops, and 11 percent cotton. Included in these classifications are practically all types of irrigated crops grown in any of the western states.

The presently irrigated lands within each of the seven hydrographic areas of the state used in Bulletin 2 are as follows:

Area	Net Acres Irrigated	Percent of Total
North Coastal	213,000	3.1
San Francisco Bay	163,000	2.4
Central Coast	338,000	4.9
South Coastal	617,000	9.0
Central Valley	4,751,000	69.1
Lahontan	228,000	3.3
Colorado Desert	565,000	8.2
TOTAL	6,875,000	100.0

Over two-thirds of the total area irrigated in the state is in the Central Valley. No other hydrographic area contains as much as 10 percent of the total. The distribution of the irrigated area in the Central Valley is shown in the following table.

Drainage Area	Present Irrigated Area - Acres: Mountain Units	Valley Units	Total	Percent of Total
Sacramento River Basin	269,000	763,000	1,032,000	21.7
Tulare Lake Basin	12,000	1,750,000	1,762,000	37.1
San Joaquin River Basin	9,000	1,948,000	1,957,000	41.2
TOTAL	290,000	4,461,000	4,751,000	100.0

The Tulare Lake Basin is the portion of the general San Joaquin Valley above the San Joaquin River. Areas using Kings River runoff are in the Tulare Lake Basin.

Two items stand out in these results. One is the relatively small amount of irrigation that has been developed in the mountain units of the Central Valley during the past one hundred years when water has been available and many mining ditches could be used for its conveyance. Only about 6 percent of the total irrigation in the entire Central Valley is in these mountain units. About 26 percent of the total irrigation in the Sacramento Valley is in its mountain units, about 40 percent of this total area is from the Pit River and 30 percent is in the Upper Feather River drainage area.

The second item is the much greater extent of irrigation in the San Joaquin Valley than in the Sacramento Basin. The area irrigated in the San Joaquin Valley, including the Tulare Lake Basin, is nearly four times that in the Sacramento Valley. This development in the San Joaquin Valley has been accomplished with a local water supply only one-half as large as that of the Sacramento Valley.

In the Tulare Lake Basin the present development represents an acre of irrigation for each 1.9 acre-feet of mean annual local runoff. This has been accomplished by practically full use of all local supplies, importation in recent years of Central Valley Project water, and overdrafts on local ground-water supplies. The lower San Joaquin Valley area has a present development of an acre irrigated for each four acre-feet of mean annual local water supply; some additional areas can be supplied with increased storage of local water supplies. In the Sacramento River Basin there is a mean annual runoff of about twenty-two acre-feet for each acre now irrigated.

The preceding results indicate the rate of growth of irrigation in California. It was very slow prior to 1870; began to accelerate in the 1870's; continued at variable rates to 1900; then increased, reaching its maximum rate of increase from 1909 to 1919; slowed down in the 1920's and 1930's and accelerated again in the 1940's. Results for the 1950's are not yet available; the increase in irrigated area has continued but probably not at as rapid a rate as in the 1940's. The maximum rate of any decade (1909-1919) was 155,000 acres per year. This rate of increase was almost equalled from 1940 to 1950.

These variations in the rate of increase of the area irrigated are related to general factors that affect each decade. There was little interest in irrigation or population to demand its crops prior to 1880; shipments of perishable crops were limited and expensive. The depression of the 1890's checked the expansion that had begun in the late 1880's. The recovery of the late 'nineties and the generally active demand for land from 1902 to 1910 resulted in the construction of some additional works, but much of the increase in area in these years was the result of the more complete use of the systems that had been constructed previously. From 1909 to 1919 the newer projects continued to come into use; use of ground water became an increasingly important element; some new crops, such as rice, made available lands which had previously been unattractive. The decade 1919 to 1929 was one of much activity in the organization and financing of irrigation districts, but these newer projects did not get into op-

eration in time to affect materially the areas served. The rate of increase in this decade fell to about 50,000 acres per year; ground water was the source of the major part of this increase. The depression of the 1930's stopped new projects financed from local sources and brought the initiation of large multiple-use projects. These new projects were not completed in time to affect the area in 1939.

Development was retarded during the war years of the early 1940's but was accelerated very quickly as soon as equipment for pumping could be secured. This acceleration resulted from the relatively high crop prices obtainable in the later 1940's.

Other factors in the declining rate of increase in the irrigated area in recent years are the lack of remaining unused local surface-water supplies that can be made available for local projects. By the middle 1920's nearly all of the attractive local projects had been constructed and were in at least partial use. Since 1930 almost no new large projects diverting from streams have been undertaken using local financing. The irrigation development in California by projects using local water supplies on adjacent lands is now relatively complete. Further construction by such projects will be mainly by improvements in existing systems, such as supplemental storage to serve some additional lands, rather than by making available new water supplies to large blocks of new land.

Prior to 1920, storage for irrigation was relatively limited. Feasible sites had been developed much earlier in southern California, as at Hemet and Bear Lake reservoirs. Storage for irrigation in the San Joaquin Valley began in the 1920's with the construction of the Don Pedro, Melones, and Exchequer reservoirs. There are no remaining unused stream flows in the San Joaquin Valley which can be made available for dependable use without storage.

The interest which developed in the 1920's in projects of greater scope was a natural result of the full use of local sources. Unless irrigation was to stop expanding, a different type of project and a different method of financing were required. The interest in such large-scale projects developed during the boom of the 1920's and was not the result of the succeeding depression. It was brought to realization more quickly than it might have been by the depression of the 1930's but did not have its origin in the change in policies regarding public aid that grew out of this depression. Eventually some means for constructing such projects would have been found regardless of recurrent booms or depressions.

Irrigation Organizations

A distinctive feature of irrigation development in California has been the variety of the forms of irrigation organizations that have been used. The application of the principles of public improvements to irrigation districts began in the early legislation and has been amplified until there are now a large number of such forms of public districts from which any area can select the one best suited to its needs. The principal items on which these acts differ are the methods of voting, the basis for assessments, and the character and authority of their officers. Where no existing general act has appeared to meet all of the needs of some particular area, the Legislature has, in several instances, passed special acts for single projects.

Following the passage of the first general irrigation district act in 1887, there was much uncertainty regarding the construction the courts would place on irrigation as a public improvement. The principles of enforced inclusion of the nonconsenting minorities and their taxation for district purposes had been well established for those types of special improvements which had been recognized as being definitely public in character, such as school, sewerage,

or road districts. These were all classes of service in which the general public could participate in their use. Only the actual landowners benefit directly from the irrigation of their lands. Irrigation would represent a public improvement, justifying the use of the taxing power, only if its results also had general benefits. This uncertainty was settled by decisions of both state and federal courts that, for the conditions in California, where the climate requires irrigation for the adequate use and development of the agricultural lands, irrigation has sufficient public benefits to justify its classification as a public improvement.

California Irrigation Districts

The most widely used act is that which began as the 1887 Wright Act, was revised as the Wright-Bridgeford Act in 1897, materially amended in 1913, and finally designated as the California Irrigation District Act by the Legislature in 1917. This act has been amended at every later legislative session and is now sufficiently comprehensive to cover the needs of almost any conditions that may arise in districts organized under its terms. This act is the one under which over one hundred active districts are now functioning. These districts include a very material part of the total irrigation development in the state.

Another form of such districts are those designated as county water districts. These districts supply domestic water service but may include irrigation. Directors are elected and bonds may be issued. This act was passed in 1913 and has been amended and extended at later sessions.

To meet the needs of areas constructing storage for supplemental water supplies, the Water Storage District Act was passed in 1921. This act provides for assessments on the basis of benefits so that areas receiving different degrees of service may be assessed in accordance with the service to be secured. It also provides for voting proportional to the assessed value of the land each voter owns. These provisions are similar to those which have always been used in the reclamation district act in California. Where residence within the district may not be feasible or usual, the general electorate basis of voting used in the general irrigation district act is not applicable.

Special district acts for single areas are illustrated by the Palo Verde Irrigation District Act passed in 1923 to meet the special conditions in the Palo Verde Valley on the Colorado River, where flood protection, irrigation, and drainage were all needed. The Santa Clara Valley Water Conservation District Act was passed in 1921 to meet the conditions in the Santa Clara Valley, where storage and replenishment of the local ground waters was required. This district has built and is operating works for this purpose.

To permit local areas within irrigation districts to improve their local systems to the extent and at the times they might desire without having to have a general district program for such works, provision was made for local improvement districts within irrigation districts. These have been used in some districts and provide flexibility in any betterment program.

Record of California Irrigation Districts

From 1887 to 1895 there were forty-nine districts organized under the Wright Act. Twenty-four of these districts sold bonds having a par value of about $8,000,000. Many of these districts were inadequately planned; nearly all of them met financial difficulties in the 1890's. Eventually their outstanding indebtedness was adjusted by refinancing or by total collapse of the district. The record of these early districts resulted in irrigation district bonds becoming unsalable and activity in such development practically ceased until

state supervision of financing was provided in 1911. Only eight of these early districts are still operating. Among these survivors are the Modesto, Turlock, and Alta districts.

Following the failure of many of the districts organized under the 1887 Wright Irrigation District Act, the Legislature strengthened the provisions for organizing and financing such districts. This retarded district development until the organization of the Oakdale and the South San Joaquin districts in 1909. In 1911 the state irrigation district bond certification commission was created and given authority to certify bonds of approved districts as legal investments for trust and other similar funds. Such certification was expected to enable approved districts to market their bonds more readily at improved prices. To safeguard investors in such bonds, the commission was given control of many features of the bonds and the expenditures by the district of the receipts from their sale.

Beginning in 1915 activity in the organization of irrigation districts increased and reached its peak in the 1920's. During the depression in the 1930's almost no new districts were formed.

A study of all irrigation districts in California was made in 1928. The results are published in Bulletin 21 of the State Division of Engineering and Irrigation. Reports were made on 89 active districts having a gross area of 3,540,852 acres, of which 3,035,927 acres were irrigable and 1,634,183 acres actually irrigated. This area irrigated represents one-third of the total area reported as irrigated in California in the Census of 1930. Many of the districts organized in the 1920's had not completed their works and were not as yet irrigating their full irrigable areas. The area in individual districts varied from 320 to 605,000 acres.

To 1932 the irrigation districts in California had sold bonds having a par value of $109,000,000. Of this total, $69,000,000 were sold in the six years from 1920 to 1925. This represents a rate of sale over four times as large as for the preceding or succeeding years. On June 30, 1932, there were $93,400,000 of these bonds outstanding. For the forty-five years from 1887 to 1932 California irrigation districts had paid $76,000,000 in principal and interest on their bonded debt. In addition, the districts had met their operation and maintenance costs and made many improvements in their canal systems with funds obtained by direct assessment. In 1932 the delinquencies on interest and principal on the then outstanding bonds were about 5 percent of the par value of the bonds. This represents a good record of payment for the period prior to and entering into the depression of the 1930's.

During the depression of the 1930's the districts could not maintain their tax collections and extensive defaults occurred. Special state legislation providing a form of bankruptcy proceedings was passed. Refinancing through loans from the federal Reconstruction Finance Corporation was also made available. Twenty-eight California districts utilized the state supervision procedure. The Reconstruction Finance Corporation made fifty-three loans to California districts amounting to a total of $41,152,000. These loans were used to purchase and retire $75,727,000 of outstanding bonds; this represented an average purchase price of fifty-four cents on the dollar. While the outstanding bonds had a usual interest rate of 6 percent, the RFC loans were at 4 percent. As a result of this refinancing, the amount of the outstanding bonds was reduced by nearly one-half and the annual interest charges were reduced by nearly two-thirds. In succeeding years after the end of the depression, the RFC sold the bonds for California districts taken as security for its loans at a premium so that this refinancing by the government did not result in federal costs.

While the depression refinancing represented a material loss to those who had invested in the bonds of these districts, a debt adjustment to meet the depression conditions was a necessity for both the bondholder and the landowners in the districts. The only resource from which payments for the cost of irrigation works can be met, for any material length of time, is the production of the lands served. If prices prevent net returns from such production, there is no available source of funds for debt service. This was recognized by the federal government, which granted a five-and-one-half-year moratorium on the construction repayments on federally built projects during the same period.

The payment record to 1932 of the California irrigation districts can be compared with that of the federally financed projects of the U.S. Bureau of Reclamation. On a total outstanding bonded debt of about one-half of the repayable costs of the federal projects, and for a somewhat shorter average period of time of payment, the California districts had paid principal and interest in a total amount of over one and three-fourths times as large as the construction repayments on the federal projects. The actual losses to district bondholders by settlements made prior to 1932 of $11,000,000 was only one-third of the accepted losses to the government on its projects to that date. The irrigated area in the California irrigation districts in 1932 was 1,600,000 acres; the similar area of the federal projects was 1,500,000 acres for which a full water supply and canal system had been built and 1,230,000 acres for which supplemental works and water had been furnished.

In 1958 there were 113 irrigation districts in California having a gross area of 4,540,000 acres, of which 2,440,000 acres were irrigated. Over 8,000,000 acre-feet of water was delivered by these districts. From 1940 to 1958 the outstanding long-term indebtedness had increased from about $68,000,000, representing an average of about $25 per assessed acre, to about $194,000,000, equal to an average of about $52 per acre. The total long-term indebtedness in 1958 was about two-thirds in the form of outstanding bonds and one-third in the form of repayment contracts of thirteen districts with the United States for construction of works and for loans.

Since the recovery from the depression, the California districts have met the payments due on their outstanding bonds. With federal crop supports and general inflation, there should be little, if any, difficulty in meeting the future payments on the outstanding bonds of California irrigation districts.

Irrigation districts are the form of organization with which the U.S. Bureau of Reclamation usually contracts for service from its projects. Sales of water for irrigation from the Central Valley Project are made to local units organized as irrigation districts. Such districts contract for the amount of water they require and take over the operation of the local distribution system. Sale of Central Valley Project water in the San Joaquin Valley is being made to some fifteen irrigation districts. Some of these districts had been in operation, using local water, prior to the construction of the Central Valley Project and some have been organized to contract for such water.

In recent years, some irrigation districts have included power development in their storage programs. The reservoirs provide supplemental water for the districts. Where the storage can be located at elevations above the lands in the district, power heads may be available which can be developed profitably. Some recent projects are using revenue bonds to finance such developments with contracts for the sale of power covering the life of the bonds which will provide revenues to meet the bond charges. As interest on such bonds of these districts is exempt from income taxes and as the districts are largely tax exempt on their property, they can finance developments that might not be attractive to private enterprise.

Mutual Water Companies

The mutual water company, as its name implies, is a nonprofit cooperative form of organization. Landowners desiring service acquire stock in the company. The funds of the company are derived from assessments on the stock or by charges for the water delivered. Ownership of stock is voluntary, a landowner cannot be included in a mutual water company by action by others as can be done for a nonconsenting minority in an irrigation district. This is a weakness in this form of organization, as the costs of construction depend on the area covered by the irrigation systems. If a material portion of the area covered does not participate, costs for the remaining subscribing areas may be too high for the project to be feasible. In borrowing, a mutual water company can mortgage only its own property; no liens against the lands served can be created.

Mutual water companies are suited to projects where initially all the area to be served is in one ownership. They have been used in many land-colony projects. The land sales and the canal operations could be separated and a permanent obligation on the constructing company avoided by transferring water-company stock to each land purchaser. Many California mutual water companies started on this basis are now operating. This type of development is better suited to small or medium-sized projects. It has been most extensively used in southern California, where usual projects have included less than 10,000 acres.

Commercial Irrigation Companies

In commercial irrigation companies the ownership of the canal system and the lands are separate. While landowners served may own an interest in the canal system, such ownership is not required as a prerequisite to service. Commercial irrigation companies offering to serve lands within their service area are public utilities except where water deliveries are limited to certain types of contract service.

The commercial form of organization has been used in California for the development of lands wholly or largely in one ownership. By constructing the irrigation system and providing water at a specified rate, project lands could be sold at irrigated-land values. The incentive for such projects has generally been this opportunity to secure the increment in land value rather than any expected profit from the continued operation of the irrigation system.

The commercial irrigation companies that have continued in operation have generally been held to be public utilities. This results in their rates being subject to regulation by the State Public Utility Commission. While a public utility is protected against competition by other similar companies in the area for which it has a certificate of public convenience, it has no guaranteed return unless the demand for its service provides a market at a profitable rate. Many public utility irrigation systems in California have not been profitable under continued operation, although they may have met their purpose in land development and sale. In general, once the obligation of public service has been established, operation must be maintained as long as there is a demand for service unless actual losses in operation can be shown. Abandonment requires approval by the Public Utility Commission. Results compiled in 1930 (Technical Bulletin 177, U.S. Department of Agriculture) showed an average annual return for twenty-eight California public utility irrigation systems of less than 1 percent. New public utility irrigation systems have not been built in California since the end of the period of active land-colonization projects.

Many former public utility irrigation systems in California have been acquired by organizations of the landowners in their service area. The usual

practice has been the organization of an irrigation district covering the area served, and its purchase of the canal system serving it. Where the utility operations had not been profitable, such purchases have generally been made at prices favorable to the districts. Examples of such changes in the irrigation organization include the Fresno, Consolidated, Merced, Richvale, and the Central California irrigation districts. Among the larger public utility irrigation systems still operating are those of the Kern County Land Company on Kern River.

A number of the early mining systems sold water to irrigate lands along their ditches, usually to small areas. When the use of these ditches for mining ended, the rates some of these irrigated areas could afford to pay produced insufficient revenue to meet the cost of canal operation. The obligation to continue service under these conditions has been worked out in various ways. In some of the major fruit districts of the Sierra foothills, the irrigated areas have been sufficiently large and compact to enable the operation of the ditches to be continued. Use of mining ditches for power has also helped in some cases.

Land Colonies

Many of the early irrigation developments in California were of the so-called colony type, where blocks of land were secured, irrigation works built, and the land colonized for irrigation farming. Areas were obtainable for this purpose more readily than in other states, as there were many large ownerships resulting from Mexican land grants. Title to similar areas of public lands might also be secured through the Swamp and Overflow Act for lands coming within its scope or by the location of land script as a means of purchasing agricultural public lands. Such land script, which could be applied toward the purchase of public lands, was issued from time to time by the federal government in payment for military and other services.

The day of the land colony in California has largely passed. No longer are there available areas of good soil in one ownership for which a water supply can be secured at low costs. There are some large ownerships of unirrigated lands of good soil, but local surface-water supplies are generally fully used and imported water supplies are too expensive to make private developments attractive for land speculation. There are a few sources of unused water but large adjacent land ownerships are generally not of attractive quality. The above comments are merely another way of stating that almost all of the opportunities in California for low- or medium-cost irrigation works serving good lands have been developed and that future projects will be of larger size and cost than are adapted to construction for colonization purposes, unless subsidized by some form of federal or state aid. This was forcibly illustrated as early as 1918, when the then State Land Settlement Board invited offers of tracts suitable for state land-settlement colonies. Over fifty proposals were made but the Board found only four that they were willing to consider. From these four they selected the Delhi Colony near Turlock.

Local Developments

The irrigation development of California is so extensive and varied that an account of the history and results for each area would be unduly lengthy and would lack interest except to those concerned with each project. Some description of such local developments is needed, however, as a foundation for an understanding of the future potential projects and the adjustments that will be required with the present local practices.

To meet these conditions, the following descriptions of irrigation in the dif-

ferent parts of the state has been prepared. An effort has been made to select characteristic items with some special ones that may serve to lighten the monotony that might otherwise result. It does not attempt to be complete; to do so would require a large volume of its own.

Irrigation in the Sacramento Valley

There was little irrigation in the Sacramento Valley prior to 1880. The 1860's and 1870's were the time of expansion of grain growing; its success under dry-farming methods left little incentive to irrigate. When the mining ditches were closed in the 1880's by the injunctions against hydraulic-mining debris in the streams, substitute use for irrigation in the foothills was made in some cases. Following the passage of the Wright Irrigation District Act in 1887, districts including 360,000 acres in the Sacramento Valley were organized. Only a little over half of this area did any actual construction work and only a relatively small part reached and has maintained irrigation to date.

The ability to dry farm successfully in the Sacramento Valley has continued to retard the growth of irrigation there. While irrigation is essential to the production of the higher-valued crops, early land tenure in the Valley was adjusted to grain-farming practices. While the Sacramento Valley is more plentifully supplied with stream flow for irrigation than many other sections of the state, its irrigated area has not increased at as rapid a rate nor yet reached as large proportions as has been the case in the San Joaquin Valley.

Where irrigation facilities have been provided, grain growing has been replaced by crops of higher return per acre. Irrigated crops are widely diversified. Citrus fruit is grown in some selected areas; olives, prunes, peaches, apricots, pears, and almonds are among the other more prominent orchard crops. Vineyards for wine and shipment green are also grown to some extent. Alfalfa production and dairying are widely distributed. On the trough lands of heavy soil, rice is the dominant crop.

Early irrigation in the Sacramento Valley proceeded slowly. John Bidwell had 1,200 bearing orchard trees and 15,000 vines on the Rancho del Arroyo Chico in 1857. James Moore built a canal from Cache Creek in 1856, its use was small until 1864, when it was extended to a total length of nine miles. The area irrigated in the Sacramento Valley in 1907 was less than 25,000 acres; of this 7,000 acres were supplied from Cache Creek.

Early pumping plants for irrigation used the fuels then available. A 1901 report on pumping from wells near Cache Creek states all but one plant used steam power and "Straw, brush, wood and coal were used for fuel. The average price paid is 75 cents a load for straw, $4.00 a cord for wood, $8.50 a ton for coal and 11 cents per gallon for gasoline."

Ground water for irrigation can be secured in many parts of the Sacramento Valley, although there were few artesian wells even under the early conditions. In Water Supply Paper 495, 1,664 pumping plants irrigating 40,860 acres in 1913 were reported. Present ground-water draft in some portions of the Valley has become relatively heavy but extensive depletion has not occurred to date. Among the areas of larger ground-water use are the lands around Yuba City and Dixon.

The largest irrigation project in the Sacramento Valley started as the Central Irrigation District. The first survey for the Central Canal was made in 1865, construction was started in the early 1890's, and the canal operated under difficulties until 1903, when the Central District leased its works to the Central Canal and Irrigation Company. This company was succeeded by the Sacramento Valley Irrigation Company. The works were extended and an intensive land-sales program was undertaken. Later this system was acquired by the Glenn-Colusa and adjacent irrigation districts.

The Sutter Butte Canal Company started construction in 1904 to serve 80,000 acres on the west side of Feather River in the vicinity of Gridley. Colonies were used as the basis of the land sales, with water rights sold at $10 per acre. Only the main canal system was built by the canal company, with the laterals built and operated by the landowners in each colony. General crops were grown on the lands adjacent to Feather River. The introduction of rice resulted in the extension of the system to serve the heavier soils to the west. This company operated as a public utility until portions of the area served were acquired by irrigation districts.

Until the Central Valley Project was undertaken in 1935, the Sacramento Valley had the only project of the U.S. Bureau of Reclamation wholly in California. This is the Orland project of about 20,000 acres. Its water supply is secured from Stony Creek. This stream drains an area in the Coast Range from which the late summer runoff is very small. The East Park Reservoir was built when the canals were constructed. The Stony Gorge Reservoir was later built to provide additional water. For a number of years the Orland project had the distinction of being the only project of the Bureau of Reclamation which had not defaulted at any time on any payment due to the Bureau.

The other irrigated areas in the Sacramento Valley are served mainly by canals diverting from the tributary streams or are within the various reclamation districts adjacent to the main stream channels. The Sacramento Valley is an area of large potential irrigation development. Its resources have been discussed in chapter II and its probable ultimate development is considered in chapter XIII.

Irrigation in the San Joaquin Valley

Irrigation in the San Joaquin Valley started with its agriculture. Harvey J. Ostrander settled on the south bank of Merced River opposite Snelling in 1850. He farmed there and in 1854 planted alfalfa, followed in 1855 by an orchard and a vineyard. These are probably the first planting of these crops under irrigation in the valley. Lieutenant Williamson reported that a canal built on the El Tejon ranch in 1851 was used to irrigate 1,900 acres of wheat in 1853. A ditch built from Mill Creek on Kaweah River in 1853 supplied water to operate a grist mill and also to irrigate some grain and gardens. The next year two miles of the Watson ditch was built. Several ditches were built from Tule River from 1859 to 1865.

Extensive irrigation development in the San Joaquin Valley had to wait for the coming of a railroad. The Southern Pacific reached Modesto in 1870 and Bakersfield in 1874. The west-side line was begun in 1888 and reached Fresno in 1892. Construction of the Santa Fe also began in 1888 and reached Fresno from the north in 1895.

An important factor in the early development of irrigation was the trespass act of 1852. Stock grazing being more important at that time than agriculture, this law provided that an owner of crops could claim damages for injury by the stock of others only if he enclosed his crop land by a lawful fence. The cheapest acceptable fence then consisted of posts and boards. Finally, in 1872 agriculture dominated stock raising and the act was repealed. The burden was placed on the owner of stock to prevent their damaging crops, rather than on the farmer to fence or protect his fields. This act is known as the No-fence Law.

In general, irrigation began earlier in the southern portion of the San Joaquin Valley than in the north. This was to be expected. Grain could be grown with fair success with the rainfall received from the Kings River north, farther south agriculture without irrigation was precarious.

Water Resources Center Archives, University of California

Stone Dam Built about 1800 at the San Diego Mission

California Division of Highways photograph

Don Pedro Dam and Powerhouse of Modesto and Turlock Irrigation Districts

Irrigation in the San Joaquin Valley is so extensive, uses so many separate streams, makes such large use of ground water, and has been developed under so many conditions of land ownership and organizations that an attempt to describe each canal system can result only in a lengthy account of details that would obscure the main forces behind this development and the results that have been accomplished. No such detail has been attempted. Some account of the results for the areas using the different sources of water supply, emphasizing distinctive features rather than even naming all of the canals, has been used in an effort to present the general picture and illustrate the conditions and forces that produced the present results.

A similar pattern of development has been followed in the different main areas of the Valley. A few minor diversions on lands cheaply served were made prior to 1870. While the early work done was limited, the ideas of those then interested in the Valley were not subject to such restrictions and investigations looking toward larger projects were undertaken. Large areas of land could be acquired in Mexican land grants, as swamp and overflow land, by location of land script, or by other means. The large early irrigation systems were essentially land-development projects in which the construction of the irrigation canals was the means used to permit cultivation of lands in large ownerships or for colonization and sale to settlers. This continued through the 1870's and 1880's. The San Joaquin and Kings River canal from the San Joaquin River and the canals from Kern, Kings, and Merced rivers are examples of this type of development. By the later 1880's demands for irrigation for lands already in divided ownerships resulted in the passage of the first irrigation district act and the operations under its provisions during the 1890's. By the turn of the century the more favorable projects in the Valley had taken shape and, in general, had been undertaken. Increased demands for land from 1900 to 1910 resulted in the more complete use of lands under canals already built rather than the initiation of new projects. Ground water began to come into extensive use in this period. By 1910 the pressure for new construction resulted in the changes in the irrigation district act, which enabled new projects to be financed, and district organization and development was active into the 1920's. A considerable part of this activity was the acquirement and expansion of canal systems previously built and operated by private organizations; illustrations of this type are the Fresno, Consolidated, and Merced irrigation districts. In the 1920's storage became a part of projects for irrigation, either as the basis for an increase in service in existing systems, such as for the Modesto and Turlock districts, or as a basis for expansion, as for the Merced District. With storage came its by-product, power, with its help in meeting irrigation costs.

Storage and power development in the 1920's occurred in the northern part of the Valley but did not extend to its southern portion. Streams north of the San Joaquin River had been developed by one or two organizations, so that adjustment of water rights and financing of storage was relatively free from complications. From the San Joaquin River south, existing water-right conditions were more involved, there was less surplus unused water available for storage and many areas found that they could utilize the ground-water storage within their areas as a substitute for surface storage on the stream channels.

During the 1920's the relatively complete use of all local streams on their adjacent areas and the overdraft on ground water in the areas not directly replenished from the stream flow, focused local interest on more comprehensive plans for additional water supplies. These investigations resulted in the evolution of the thinking of this area and the state until it was ready and pre-

pared to receive and consider the plan for the coordinated project presented by the state in 1931. During the 1930's this plan reached the construction stage and the San Joaquin Valley portions of the original Central Valley Project are now operating.

This sequence in the San Joaquin Valley is a natural one. It is a long step from the small earlier canals through the privately-financed larger systems, the locally publicly-financed irrigation districts using local waters on local areas under local initiative and control to the present federally-financed comprehensive system with its federal control.

In the San Joaquin Valley the available single-purpose projects locally financed, either privately or by irrigation districts, have been built. Some opportunities for joint irrigation and power developments remain. Without power to help meet the costs, such projects cannot meet the economic competition of the more liberal terms on which federal funds have been made available even where the physical opportunities for such local additions to the present systems may be available. While the future in the Valley holds the promise of much greater schemes than those responsible for its early development even pictured, the courage and initiative that gave the Valley its start and carried it through the first sixty years of its development laid the foundation for the projects now under way or being planned.

Prior to its extensive use, the ground water under much of the trough lands of the Valley was under pressure, so that flowing wells could be obtained. These were used for early irrigation. Later, with heavier drafts, the pressures diminished, so that pumping was required. There are practically no flowing wells remaining in the Valley, although some flow may occur during winter months of reduced pumping draft. This artesian flow was of material help in the period from about 1880 to 1900, as pumping equipment had not been developed to its present dependability and economy.

About 1900, electricity began to be available and is now the prevailing form of power used for pumping. Plants adjacent to natural-gas pipelines may obtain power from this source.

The use of ground water in the San Joaquin Valley in 1906 is described in Water Supply Paper 398. There were 522 artesian wells measured, having a total yield of 140 second-feet; nearly all of this discharge was obtained from the wells in the southern portion of the Valley. There were 597 pumping wells reported, having a total discharge of 760 second-feet.

It is estimated that there were 5,000 pumping plants in the San Joaquin Valley in 1910. By 1920 this had increased to 11,000, and by 1930 to 23,500. In 1940 the census also reported 23,500 plants. During the 1930's abandonment equaled the new plants installed. During the early 1940's war restrictions prevented increase in the number of wells and difficulty in securing equipment delayed new installations after the removal of these restrictions. New plants have been added relatively rapidly in the succeeding years.

The preceding paragraphs have sketched and summarized the development of irrigation in the San Joaquin Valley. The following discussion of the local areas in the Valley presents illustrations from the history of these areas on which the preceding conclusions are based.

Irrigation from Kern River

Kern River formerly divided on its delta, part of the flow reaching Kern and Buena Vista lakes on the south and part going to the north through Goose Lake Slough or the swamp along the valley trough. The first ditches were built in 1858 with about 700 acres irrigated by 1867. By 1873, six canals irrigated about 7,000 acres. By 1880 the area irrigated had increased to 40,000 acres.

The Kern Island canal, built in 1861, was the first of the larger diversions. It passed through Bakersfield, where a drop of twenty feet furnished power for a flour mill. In 1877 this canal adopted rates based on the amount of water used; this may be the first of this practice for irrigation in the San Joaquin Valley, although such rates were usual in early mining practice.

Following the passage of the desert land act in 1877, much of the even-numbered sections north of Kern River were acquired under its terms. J. B. Haggin bought the odd-numbered sections covered by the railroad land grant. Entrymen under the desert land act bought water rights from Haggin's canals for proof of their water supply. Attacks on this practice caused Haggin to publish a book containing about three hundred pages of affidavits, usually of one or two pages each, stating the personal knowledge of the affiant of these lands and their desert character. The need of these lands for irrigation is now accepted without question.

An early proposed project shows that the ideas of the times were not restricted even if the ability to carry them out may have been. A prospectus of the Kern Valley Colony in 1878 presented the advantages that would result from a navigable canal from Kern County to San Francisco Bay. The Kern Island Canal was stated to have been designed as the first link in a system of canals which would carry out such a project.

In an article in the Irrigation Age in the 1890's, the system of the Kern County Land Company is described as the greatest irrigated farm in the world. The company owned 400,000 acres and at one time had 125,000 acres in alfalfa. Water was run from one large check to the next so that eight irrigators could irrigate 1,000 acres per day. Colonies had been established and land with water was being sold for $60 to $100 per acre. Many of the early settlers were secured from England.

The decision in Lux vs. Haggin (see chapter III) resulted in the Miller-Haggin agreement of 1888. This agreement provided for the division of Kern River between the upper and lower users based on measurements of the daily flow. Its enforcement required accurate records of the flow. Such records were started in 1893 and are one of the longest continuous records on any California stream. For nearly fifty years these records were secured by A. K. Warren, who developed methods applicable to the shifting channel and fluctuating flow which have aided in later work on other similar streams.

Irrigation continued using the unregulated flow of Kern River with some storage in Buena Vista Lake for the lower lands. In 1919 interest in storage on the upper river led to a cooperative study by the state and local interests. The organization of local districts and the construction of storage at Isabella were recommended. The upper lands organized the Kern River Water Storage District, this district did not succeed in working out an acceptable plan for the acquirement of the existing canals in its area and was later dissolved. The Buena Vista Water Storage District was organized for the lower lands, and acquired the canals serving this area.

When construction of flood-control projects was adopted as a federal policy in 1936, investigations of storage at Isabella for flood control were made and a flood-control project was authorized in 1944. This has been constructed with a capacity of 570,000 acre-feet and regulates almost all of the total runoff of Kern River for both flood control and irrigation.

Use of ground water for irrigation was active in Kern County by 1902. The Wasco Colony was started in 1907, based on the use of wells for the water supply. The first wells at Edison were drilled in 1908 and the first citrus there was planted in 1909. Delano began its development in 1908 but progress was slower as a result of its higher lifts and costs. The ground-water depletion in

these areas provided a large part of the incentive for the effort to secure an imported water supply, which resulted in the plans for and the construction of the Central Valley Project.

Irrigation in Tulare County

The principal streams in Tulare County are the Kaweah and Tule rivers. Early conditions are described in the 1880 report of the State Engineer. Kaweah River divided into eight or ten channels on its delta. The St. Johns Channel was formed by the flood of 1861-62. The first diversions for irrigation began about 1857. In 1879 only 3,000 acres were irrigated near Visalia, due to deficient stream flow in that year although about 9,000 acres had been irrigated in other years.

The Tulare Irrigation District was organized in 1889 and began to make plans for its works. A committee was sent to southern California to investigate what had been done there. They were cordially received and returned greatly impressed with what they had seen. A portion of their report justifies quotation as a tribute to their hosts and a recognition of the high standing of civil engineers:

"It would be difficult to overestimate the efforts made by civil engineers, public officials and private citizens wherever the committee went to furnish information and advice, even spending valuable time in taking them over the country and showing them everything worthy of notice in their line of inquiry. If the civil engineers of southern California are an average representation of their profession, the committee are inclined to place civil engineering at the head of all the professions in producing notable and generous manhood."

The same attitude attributed to the civil engineers in the above quotation, if adopted by all concerned, would be a very useful factor in solving the controversial matters which, in recent years, have obscured the real interests and objectives of the state in its efforts to develop its water resources.

Several canals divert from Tule River. The upper diversions serve citrus areas, the lower ones general crops. In some years no flow from Tule River reaches Tulare Lake.

Earlier use of ground water was from artesian wells. Such flow could be secured in the area between the Southern Pacific Railway and Tulare Lake. In 1881 a seven-inch well, 330 feet deep, located three miles west of Tulare, had a flow of 800,000 gallons per day. As this well had been located by a water witch, a celebration was held in his honor. It was reported that pieces of charcoal, nut shells, and wood were found at a depth of 320 feet in this well. In 1885 local land-advertising pamphlets claimed that the average artesian well would irrigate 160 acres, with some wells producing enough water to serve 320 acres of trees or vines.

The increase in pumping draft after about 1910 has reduced the artesian pressures so that flow no longer occurs except occasionally a few wells may have a small flow during the winter months.

Ground-water pumping for irrigation began relatively early in Tulare County. Several steam-powered pumps were in use near Lindsay by 1894. The rapid increase in pumping after 1910 resulted in overdraft in areas lacking direct sources of recharge. Meeting this overdraft had to wait for the completion of the Friant-Kern Canal of the Central Valley Project.

Flood-control storage projects on both the Kaweah and the Tule rivers were authorized in 1944 and are now under construction. These reservoirs at Terminus and Success, respectively, will control the flow of these streams for both flood control and irrigation.

Irrigation from Kings River

Kings River has built a ridge across the San Joaquin Valley with the eroded material it has brought down from its upper drainage area. The river divides on the ridge, part flowing to the south into the sump it has created behind its ridge and part to the north through Fresno Slough to the San Joaquin River. This sump, the Tulare Lake Basin, also receives inflow from the Kaweah, the Tule, and the Kern rivers.

The channels of Kings River on its delta have been subject to change. At times of some floods, new channels have been formed and old channels partly filled. Further changes are now controlled by diversion structures and the river has been stabilized in recent years.

There was only very limited use of Kings River prior to 1866. Some settlement occurred in the following years and canals were gradually extended to serve adjacent lands. Some delivery in the vicinity of Fresno occurred by 1871. Upper diversions were opposed by the lower riparian owners and many lawsuits were filed. In spite of these controversies, a fairly complete system had been built by 1886, when the Fresno Canal Company was sold to the English interests then owning the larger part of the lower riparian lands.

The lower south-side canals—the Peoples, Last Chance, and Lemoore—were built in the 1870's. The system of the present Alta Irrigation District was built by the 76 Land and Water Company, which was incorporated in 1882. At that time this company owned 30,000 acres of land and had constructed fifteen miles of canal. In its advertisements in 1884 the company claimed to have sufficient canal capacity to serve 220,000 acres. It offered lands for sale "including a permanent water right" at prices varying from $15 to $60 per acre.

The State Engineer reported in 1880 that about 85,000 acres were being irrigated from twenty-one ditches. This has increased until the service area of Kings River includes about a million acres, with about 700,000 acres actually irrigated. Kings River, prior to the construction of Pine Flat Reservoir, was probably the most completely used of any California stream on which storage had not been constructed. Large diversions at times of high runoff provided percolation to the ground water which was pumped from wells at times of deficient stream flow. By 1950 there were over 12,000 individual wells in the Kings River area. These had been installed and were operated by the individual landowners.

The areas served by Kings River include several irrigation districts. The Fresno, the Consolidated, the Laguna, and the Riverdale districts were organized in the 1920's and purchased existing canal systems irrigating their areas. The Alta District was organized in 1888 and acquired the system serving its area. All of these districts secured their irrigation works at relatively low costs per acre and have paid off the bonds issued for this purpose.

Some of the smaller irrigation districts on the North Fork of Kings River had higher costs and encountered financial difficulties. The James District included part of the former James Ranch. Both reclamation from overflow and drainage were required as well as irrigation. These combined costs exceeded the financial capacity of these lands and refinancing was required. The land in the Stinson District was originally a large holding which was subdivided, encountered financial troubles, and passed back into a large ownership.

Investigations of storage sites on Kings River were made from time to time but did not produce specific results until the Corps of Engineers, U.S. Army, made investigations of the feasibility of storage for flood control following the passage of the 1936 flood-control act. In 1921 and 1923 local interests had secured the passage of acts adapted to the construction of storage by irrigation units joining for such a purpose without affecting their individual distribution

organization but neither of these acts was used to complete an organization under their terms. The desire for storage was one of the incentives for the agreement on water rights which has been discussed in chapter III. When the Army Engineers made their investigations in 1938, the U.S. Bureau of Reclamation also undertook studies of storage. Both agencies made reports which were published as House Documents 630 and 631, 76th Congress, Third Session. The local interests had made applications to appropriate water for storage as early as 1916 and had surveyed the Pine Flat Reservoir area and drilled its dam site prior to the federal work.

The U.S. Army Engineers recommended storage at the Pine Flat site having a capacity of 1,000,000 acre-feet to be used for both flood control and conservation. About one-half of this capacity was to be reserved for the control of winter floods and the entire capacity was to be made available for storage of summer snow-melt floods in years when snow surveys indicated it would be needed. Water stored for flood control would be held for release for irrigation after the flood season had passed.

The project recommended by the U.S. Army Engineers was authorized in 1944 and the Pine Flat Reservoir was completed in 1953. It has operated in accordance with its plans and has resulted in material flood control and irrigation benefits.

The Pine Flat project has been involved in extended conflict regarding which federal agency should contract with the local users of the irrigation storage and the applicability of the terms of the reclamation act to such contracts. Pine Flat is operated by the U.S. Army Engineers but the contracts for irrigation use are to be made with the U.S. Bureau of Reclamation. To date, operation has been on an interim year-by-year basis pending completion of a permanent contract.

Tulare Lake

As Tulare Lake has received the variable inflow of its tributary streams, its elevation and area have been subject to wide fluctuations. Prior to diversions for irrigation, Tulare Lake rose above the elevation of its north rim and overflowed to Fresno Slough at times of above-average runoff. At other times, inflow was balanced by the evaporation from the lake. Since its tributary streams have been used for irrigation, only flood waters have reached the lake and overflow has not occurred since 1878. In recent years the lake has been dry except in occasional years of surplus runoff when varying areas up to 100,000 acres have been submerged. The former lake bed now consists of reclamation districts with levees to protect against overflow. When inflow occurs, breaks in such levees provide space in which the inflow can be ponded until it can be used or is evaporated.

Federal flood-control projects based on the construction of reservoirs on the four tributary streams were authorized in 1944. Pine Flat Reservoir on Kings River and Isabella Reservoir on Kern River have been completed. Terminus Reservoir on Kaweah River and Success Reservoir on Tule River are under construction. These projects will provide protection against uncontrolled inflow into Tulare Lake except in infrequent years of very large runoff.

The history of Tulare Lake illustrates the varying conditions to which it has been subject. Accounts of its condition at the time of statehood have been presented in chapter I.

An account of early conditions on Tulare Lake is contained in a report of the Examining Commission on Rivers and Harbors in 1890. Following several years of excess rainfall, Tulare Lake was full in 1853 but did not reach as high a stage as in 1862 and 1868. From 1853 to 1861 there was a recession, reaching elevation 204 in 1861. The flood flows of 1862 caused a rise of 16 feet

and an increase in the area of the lake from 300 to 800 square miles. The retained inflow exceeded 5,000,000 acre-feet. Additional water was discharged to Fresno Slough, as the lake at its maximum state was six feet above the elevation of its outflow. By 1867 the lake had lowered twelve feet; the flood flow of 1867-68 raised it nearly to the height reached in 1862. From 1872 to 1876 the elevation of the lake varied from three feet above to three below the elevation of outflow; by November 1883 it was 22 feet below its rim. No further outflow occurred prior to this report in 1890 and none has occurred since that date.

In commenting on the effect of irrigation on Tulare Lake and on its history prior to the above records, the Commission stated:

"Although such diversion must produce some effect on the lake, the evidence that protracted low stages preceded that of 1883 is conclusive. On the northeastern shore of the lake, close by the mouth of Mussel Slough there is a group of tree stumps, at an elevation of about two hundred feet. These were found at the water's edge in 1882. They presented the appearance of having been broken off at a height of three to four feet above ground. They were well preserved and must have been under water for nearly thirty years succeeding the high stage of the lake of 1853. These stumps are the remnants of a grove of willow trees, one hundred or more, of which some had grown to a diameter of four feet. It would not have been possible for these trees to attain such growth if the lake had not been at a low state for many years in succession at some time preceding 1853."

The datum for the elevations given in this report differ from those now in use. The present elevation of the outflow is 207 feet and of the bottom of the lake 179 feet. In 1882 the lake was at elevation 194, giving a depth of 15 feet and an area of 350 square miles. There are earlier records of the lake having been below this elevation but none lasting sufficiently long to enable these trees to grow. As quoted, the Commission concluded that they must have grown prior to 1853.

Tulare Lake became dry in 1899 and 1900, partly refilled in 1901, became dry in 1905, filled to an area of about 200,000 acres in 1906, was almost dry in 1914 and 1915, refilled to about the 1906 elevation in 1916 and became dry from 1919 to 1936 except for a small inflow in 1922. In 1938 inflow exceeded the capacity of the area reserved for flooding and about 100,000 acres were submerged. The lake became dry again in 1946 and, except for limited amounts of flooding, has remained dry to date except in 1952. As the lake has receded, levees have been built to confine its area so that the unwatered areas could be cropped. The lake-bed soils are fertile and the yields of grain and cotton have been large. The danger of submergence has prevented residence within the lake bed and farming operations are handled in large units with equipment quickly removable at times of flooding.

The area in the Tulare Lake was organized as the Tulare Lake Basin Water Storage District in 1926. A plan was adopted and an assessment was made to distribute its costs. The storage district has operated to represent its owners in negotiations relating to water rights and to flood-control projects affecting its area. Use of water within its area is handled by the included reclamation districts and other organizations.

West Side of Tulare Lake Basin

This area extends from Mendota southerly around the west side to Wheeler Ridge. There is practically no surface stream flow from its tributary drainage areas. To date, its water supply has been limited to its local ground water.

Pumping from wells in the Mendota area began over thirty years ago. It was

soon recognized that such draft was depleting the accumulated ground water at a rate exceeding its recharge. Following World War II the area irrigated increased rapidly as the result of favorable crop prices, particularly for cotton. The deep wells required have such large costs that small land ownerships are not usable under present conditions. Farming has been in large ownerships with little local urban development. The ground water has lowered rapidly under the recent rates of use.

Farther south little development has occurred in the Antelope Plains except near Devil's Den. Increased use of its local ground water in the Wheeler Ridge area in recent years has also resulted in material ground-water depletion there. In this area potatoes as well as cotton have been principal crops.

The proposed San Luis Project of the U.S. Bureau of Reclamation would serve about a half million acres of the west-side lands between the northern line of Fresno County and Kettleman Hills. The state's Feather River Project also proposes to import water for use on these lands. Both projects have been urged as a means for preventing the presently irrigated lands from being abandoned. Without some source of imported water, the continued ground-water lowering under present drafts will, in time, result in pumping lifts, under which the cost of pumping will exceed the value of the use of the water secured.

These San Luis area lands, prior to their irrigation, had only a small agricultural value. The rapid development of this area following World War II brought the larger part of these lands into use prior to 1950 during a period of federal crop-price support for cotton without acreage restrictions and provided the cotton history for its continued production after acreage controls were established. These conditions resulted in an opportunity to secure the return of the capital investment in the irrigation of these lands relatively quickly. This development was based on the use of a water supply which had been shown to be inadequate to sustain permanent irrigation by the results of the more limited prewar use.

At present both federal and state agencies are proposing projects for this area which will provide an imported water supply to replace the present ground-water overdraft. The large-scale farming practices have resulted in a minimum of local settlement and improvements. There is no other California area of similar size where present irrigation could be abandoned with less effect on the over-all economy of the state. Justification for projects to provide a new source of water for this area should be based on the future uses which can be made of these lands rather than the salvaging of past development.

Irrigation from the San Joaquin River

The San Joaquin River enters the valley near Friant, flows westerly to the valley trough near Mendota, and turns northerly to follow the valley to sea level. It receives no useful inflow from its westerly tributaries within the valley. From the east it is the outlet of the streams draining the western slope of the Sierra. Its own Sierra flow is diverted above the mouth of the Merced River, lower diversions during low-water periods are dependent on inflow from the east-side tributaries.

The San Joaquin River was the source of water supply for the earliest large irrigation system built in California. This system, the San Joaquin and Kings River Canal, has operated to serve a large area on the west side of the Valley, extending about one hundred miles northerly from Mendota. Like other early systems, it had its financial difficulties.

The San Joaquin and Kings River Canal and Irrigation Company was incorporated in 1871. By 1873 it had constructed forty miles of canal from Mendota. This canal was fifty-four feet wide at its water surface.

The engineer for this system in its early years was R. M. Brereton, an Englishman who had worked in many parts of the world. His published reminiscences cover much of the early history of this project. He began his work in 1871 and constructed sufficient canals to enable 5,000 acres to be irrigated and to demonstrate the results which could be secured.

The conditions under which the early construction was handled are described as follows in a report by Brereton. He states:

"The Chief Engineer has only recently taken charge of the works, and has no staff to enable him to determine the levels, and consequently he is obliged, as the construction is being pushed ahead, to carry the canal just wherever the contour line will admit of the present grade being carried with economy in excavation, and this makes the canal more crooked than it perhaps would otherwise be."

The State Engineer in 1880 reported the San Joaquin and Kings River Canal as having a length of sixty-seven miles and a cost to that date of $1,300,000. On the first thirty-nine miles, check gates were constructed at intervals of four to five miles. Five of these structures included drawbridges to permit the passage of canal boats. When the canal was extended, navigation had been abandoned and the drawbridges were omitted. At the headworks, a sluiceway on the west end was provided with a capstan by which steamers and barges could be drawn up through the sluiceway during the navigable season. The State Engineer commented:

"Irrigation and navigation were found to be wholly incompatible without a system of locks to avoid the annoyance to the irrigators of opening the stop gates for the passage of the canal boats, and the waste of water and time incident thereto."

The San Joaquin and Kings River Canal operated as a public utility until recently, when it was purchased from Miller and Lux by the Central California Irrigation District. This district includes the area formerly served by this canal.

Efforts to irrigate lands on the east side of the valley in Madera County began soon after the first irrigation district act was passed in 1887. The Madera Irrigation District was formed but was unable to secure funds for construction; it was dissolved in 1896. The present Madera Irrigation District was organized in 1920. It included 350,000 acres. A bond issue of $28,000,000 was voted in 1921 but only a small amount of this issue, used for preliminary costs, was sold. Controversies over water rights with areas diverting farther down on the San Joaquin River led to an attempted compromise by the organization of the San Joaquin River Water Storage District in 1922. The efforts to work out a satisfactory plan for this district did not succeed and it was dissolved in 1928. The Madera Irrigation District then resumed its efforts to proceed with its own development. The area in the district was reduced by about one-half to exclude shallow hardpan and alkali soils. Further litigation prevented carrying out the district project. The district has now become a unit in the Central Valley Project and received its first water service from the Bureau of Reclamation in 1944.

Diversions for the west-side lands along the lower portion of the San Joaquin River are made by means of pumping plants. These plants serve the area north of that served by the San Joaquin and Kings River Canal. Both the flat grade of the river and the necessity of locating the diversions below the points of inflow from east-side tributaries controlled the selection of such pumping plants.

The Patterson project was the first pumping system diverting from the lower San Joaquin River. Construction began in 1909; the project now serves 19,000 acres of a former land grant. It was operated by the constructing com-

pany until taken over by the landowners as stockholders in a mutual water company. A similar system at Brentwood has become the East Contra Costa Irrigation District. Other pumping projects include the West Stanislaus, Banta-Carbona, West Side, and Byron Bethany irrigation districts. In these systems water is raised up the west-side slopes in a series of step lifts with canals from each lift serving the lands in its zone. As many as seven stages are included, with the total maximum lifts as high as 175 feet.

Artesian wells, adequate for stock use, were secured on the Chowchilla Ranch as early as 1881. Ground-water conditions on the west side of the Valley are generally less favorable than on the eastern side. The west-side alluvial fills are less coarse and the quality of much of the ground water is poorer. Pumping for irrigation has come into extensive use on the southern portion of the west side, using wells having depths in excess of 1,000 feet and relatively high costs for both construction and operation. On the east side in the Madera area about 100,000 acres have been irrigated from wells.

Irrigation from Merced River

By 1880 about 1,500 to 2,000 acres were irrigated in the bottom lands along Merced River. The Farmers Canal, diverting about three miles below Merced Falls, was started in 1873. Some irrigation under this system started in 1880. This canal was sold to what became the Crocker-Huffman Land and Water Company after passing through other intermediate names. The diversion canal to Lake Yosemite, storage there, a municipal pipeline to Merced, and canals to serve adjacent lands were built prior to 1888. The reported cost was $2,000,000. At one time seven hundred men and five hundred mules were employed on the canal construction.

The Merced Irrigation District was organized in 1919 to include 190,000 acres. It acquired the Crocker-Huffman canal system serving part of its area, built new canals for the remainder, and constructed the Exchequer Dam on the Merced River. A material item in the cost of the reservoir was the relocation of the railroad to Yosemite Park which had been built through the reservoir site. This railroad has since been abandoned. A power plant was built at the Exchequer Dam and a contract was made for the sale of the power output to the San Joaquin Light and Power Corporation. A total of $16,000,000 in bonds was issued and sold to meet these costs. The district carried its financial load into the 1930's. As much of the land in the district had not been placed in irrigation and crop returns on the remainder were low during this period, extensive tax delinquencies occurred. The district went through the form of bankruptcy provided by federal law and refunded its bonded debt through the Reconstruction Finance Corporation at fifty-one cents on the dollar. The average net income under its power-sale contract has been a major item in meeting the interest and principal payments on the refunded bonds. The district is now proceeding actively with plans for an enlarged storage and power development on the Merced River.

Irrigation from Tuolumne River

Efforts to secure irrigation from the Tuolumne River were persistent but required over thirty years for their accomplishment. In 1852 the Wheaton mining dam was built at La Grange. It was used to irrigate some nearby bottom lands.

In 1877 an effort was made to secure subscriptions for stock in a Mutual Water Company. A report was made by William Ham Hall in which he found 100,000 acres between the Tuolumne and the Stanislaus rivers which he esti-

Courtesy of California Department of Water Resources

Irrigation in Yolo County. Siphoning Water to Furrows

Courtesy of California Department of Water Resources

Orchard Irrigation in Santa Clara Valley

U.S. Bureau of Irrigation photograph

Furrow Irrigation

U.S. Bureau of Reclamation photograph

Vineyard Irrigation in the San Joaquin Valley

mated could be irrigated at a cost for construction of $3 to $4 per acre for main canals and a similar cost for laterals. Sufficient stock subscriptions were not secured for this project.

In 1886 C. C. Wright was elected to the Legislature for the purpose of attempting to secure the passage of a workable general irrigation district act. Such a bill was drafted, given careful study by the Legislature, and passed in 1887. As previously discussed, this has come to be known as the Wright Act.

The Modesto and the Turlock irrigation districts were organized in 1887. The present La Grange Dam was built in 1891 to 1893 at a cost of over one-half million dollars. Litigation during the 1890's delayed progress and the first water deliveries did not occur until 1900 for the Turlock district and 1903 for the Modesto district. Collection of taxes was enjoined from 1897 to 1900. A writ of mandate was secured to compel holding an election in 1901 in the Modesto district and a Board of Directors favorable to irrigation was elected. Terms for refunding the early bond issue were worked out and the bonds were voted. The completion of the system in 1904 was celebrated with a jubilee. In 1912-13 the Modesto district built the Dallas-Warner Reservoir. In 1923, jointly with the Turlock district, the Don Pedro Reservoir was completed at a cost of $3,750,000. Power was developed at Don Pedro Dam and distributed to the landowners in the two districts. These were the first districts in California distributing power as well as water to their district area.

The Turlock district was also organized in 1887, adopted a plan and voted bonds in the same year. The second bond issue was voted in 1892. This district encountered similar difficulties to those met by the Modesto district but was able to make its first delivery of water in 1900.

While the Modesto and Turlock districts are now representative of the more successful irrigation projects developed under the district form of organization, the actual irrigation of their lands proceeded slowly in their early years of operation. The total area in the Modesto district is 81,000 acres and in the Turlock district, 185,000 acres. By 1920 the Modesto district irrigated 59,000 acres and the Turlock district irrigated 103,000 acres.

As discussed in chapter VII, the City of San Francisco secures much of its municipal water supply from the Tuolumne River by means of its Hetch Hetchy project. In the earlier years of this project there were conflicting interests between the city and the irrigation districts. In recent years these differences have been adjusted and all parties are proceeding on joint projects to develop more water and power and to provide flood control. The federal government is participating in the flood-control portions of this project by payments based on the flood-control benefits to be secured.

Irrigation in San Joaquin County

The State Engineer in 1880 reported three mining ditches on the Stanislaus River above Knights Ferry which were also used for some irrigation. A canal to lands along Littlejohn Creek had been projected. There was some irregular irrigation of grain from Calaveras River. A dam had been started which was to be used to divert for irrigation on the south side of the Mokelumne River.

The principal systems using the Stanislaus River are the Oakdale and the South San Joaquin irrigation districts. These two districts were organized in 1909 and led the way in irrigation-district activity under the revival of the use of this form of organization after its difficulties during the 1890's. The Oakdale district includes 74,000 acres of the upper-valley lands on both sides of the river; the South San Joaquin district includes 67,000 acres of lower land on the north side of the river. Both constructed their irrigation systems

and began operation by 1915. By 1924 the areas served could not be adequately supplied from the natural flow of the Stanislaus River and joint storage was constructed at Melones. The South San Joaquin district had previously built the Warner Reservoir. The opportunity to develop power at Melones was used to secure returns sufficient to meet the cost of storage there.

Both of these districts encountered financial difficulties in the 1930's and were refinanced through the Reconstruction Finance Corporation. Much of the Oakdale district is a rolling hardpan soil not well adapted to the crops generally grown in the earlier years of the project. The introduction of permanent irrigated pastures, largely Ladino clover, provided a profitable crop for these lands. The increasing use of water resulted in the need for additional storage. These districts have recently completed the Tri-Dam Project, consisting of three dams and power plants. This project was financed by revenue bonds with the revenues provided by a contract for the sale of the project power. The power is sold wholesale to the Pacific Gas and Electric Company at rates which will meet the project costs during the life of the bonds.

Lands adjacent to the Mokelumne River are irrigated mainly from wells. These sources of water supply are used in the highly developed table-grape area around Lodi. The principal present uses of this stream are for power on its upper portion and for municipal use in the East Bay area of San Francisco Bay.

San Joaquin County also includes a large part of the Sacramento–San Joaquin Delta. These lands are irrigated by water taken from the adjacent tidal channels. As the irrigation of these lands requires the prior construction of levees to reclaim them, they are described in chapter IX under Reclamation.

Sierra Mountain Valleys

Irrigation is practiced in the Sierra mountain valleys where water supply and soil conditions permit. As a result of their shorter growing season and transportation conditions, forage production has been the basis of their practice. These upper areas have climatic conditions similar to those in the Rocky Mountain states. This enables the statement to be made that, while California has some climatic and crop conditions not found in other western states, somewhere in California a place can be found which has any condition that occurs in any other western state.

The largest of the Sierra irrigated areas is supplied from Pit River. Other mountain valleys include the areas irrigated from Shasta and Feather rivers and, in the Great Basin, from Susan, Truckee, Carson, and Walker rivers. While the last three of these streams supply some land in California, the main areas which they serve are in Nevada. The total area irrigated in the Sierra mountain valleys is about 3 percent of the total for the state.

The upper Feather River areas have been prominent in recent discussions of the Feather River Project in connection with their ultimate needs and reservations of water for this area of origin. Extensive investigations by the state have found only a limited amount of feasible irrigation development. The Legislature has authorized five reservoir projects in the upper Feather River drainage area having a total storage capacity of about 180,000 acre-feet, an estimated cost of about $6,000,000, and making available an estimated mean annual water supply of about 25,000 acre-feet. As the recreational use will be mainly nonconsumptive, projects found to date have a total demand which would reduce the present flow of the Feather River by less than 1 percent. On this upper drainage area, physical conditions appear to limit the effect of any reservations, for the higher areas of origin, to a nominal proportion of the total flow. There are other projects which would divert Feather River water above Oroville for use in the foothills and in the Sacramento Valley.

Sierra Foothills

The term foothills is generally used to describe the area between the flatlands of the Sacramento and the San Joaquin valleys and the higher mountain areas. It extends generally to elevations of 2,500 to 3,000 feet and has climatic conditions suited to the production of deciduous fruits as well as forage and other crops. Its largest irrigated areas are in the Placer County fruit belt. There is only limited use of foothill lands for irrigation in the San Joaquin Valley.

In 1880 the State Engineer estimated that the total use for irrigation from mining ditches might equal 300 second-feet, with 9,000 acres irrigated. These areas were in generally small and scattered pieces under a relatively large number of such ditches. Where soil conditions permit and water can be secured, irrigation of the foothill lands has expanded. The more extensive irrigated areas are in the vicinity of Auburn, extending generally north into Nevada County and south to Placerville. The present total area irrigated in the Sierra foothills is about 1 percent of the total area irrigated in the state.

Northern Coastal Areas

This area has a large total runoff but only a limited proportion of agricultural land. This land has been used largely to grow grain without irrigation. Logged-off land may be used for pasturage. Use of irrigation is increasing, mainly in individual systems pumping from wells or streams. Permanent pastures are irrigated by sprinkling methods. The present total area irrigated in the northern coastal counties is about 250,000 acres, equal to about 4 percent of the total for the state. While irrigation in this area will probably not become extensive in terms of its total area, it will be used wherever its returns, in comparison with other agricultural methods, may justify its costs. This area generally has available water supplies in excess of its demands for irrigation.

Central Coastal Areas

This area includes the coastal valleys from San Francisco to Ventura County. The largest areas irrigated are those tributary to San Francisco Bay and along the Salinas River.

San Francisco Bay

Some irrigation, largely truck crops and orchards, is practiced on the lower lands surrounding San Francisco Bay. This is generally a narrow area except in the Santa Clara Valley. The water for irrigation is secured from wells. The excess of the draft over the replenishment has resulted in the lowering of the ground water below sea level under some of the lower lands and salt-water intrusion has become a menace in such areas.

Santa Clara Valley

An early view regarding conditions and the need for irrigation in the Santa Clara Valley is an account in a report of the U.S. Geological Survey in 1871. Professor G. N. Allen reported one forty-acre area of small fruits and berries was being irrigated from three artesian wells 300 feet deep. These wells had flowed but one had recently ceased to flow as a result of dry years and the drilling of too many other wells. A pumping plant driven by a steam engine was installed and sufficient water secured to irrigate the forty acres once per week. Local opinion was quoted to the effect that large fruit trees should be irrigated in dry years. These early comments were forerunners of the

extensive ground-water development that has taken place. Irrigation of all crops has become usual and has resulted in material ground-water depletion.

About 120,000 acres in the valley are used for crop or for municipal purposes and secure their water supplies from about 2,000 wells. From 1916 to 1934 the ground water lowered an average of about one hundred feet. Artesian pressures were lost and the ground water fell below sea level on the lower portions of the valley. This ground-water lowering resulted in a land subsidence extending to San Jose and included an area of about two hundred square miles. In some areas such lowering exceeded five feet.

To meet the conditions in its area, the Santa Clara Valley Water Conservation District was formed. Storage on the tributary streams, spreading works and canals into portions of the district not readily recharged by streams, has been built. The reservoirs are used to retain flood waters which would otherwise waste into the Bay until they can be released at rates which will percolate to the ground water.

The state proposes to supply supplemental water from the Feather River Project for areas in southern Alameda County and in Santa Clara and San Benito counties through the South Bay Aqueduct and a tunnel under Pacheco Pass.

Salinas Valley

Early maps refer to this area as the "Salinas Desert." It is now one of the most highly developed and productive areas in the state.

There was some minor irrigation prior to 1800 at San Antonio and Soledad missions. Title to much of the land in the valley is based on Mexican land grants. Early use of these lands was for dry farming or stock raising. The stream flow is limited to the winter and spring runoff and practically all irrigation is by pumping from wells. Earlier pumping was largely for sugar beets; the production of vegetables, particularly lettuce, had become extensive by 1924. The total area irrigated in 1889 was less than a thousand acres; this had increased by 1919 to 47,000 acres and by 1958 to about 150,000 acres.

By 1944 the pumping draft had resulted in salt-water contamination in some wells near the coast. Investigations were made by state and local agencies. In its Bulletin 52 the state found overdraft in two areas in the valley and proposed the construction of an East Side Canal. After continued investigations, the Monterey County Flood Control and Water Conservation District constructed Nacimiento Reservoir on this main tributary of the Salinas River to supply water for increased ground-water recharge. This reservoir of 350,000 acre-feet capacity was financed by the district without state or federal aid. It provides flood control, water conservation, and recreation. Direct diversion to the areas of deficiency of the water supplied from this and other reservoirs will probably be needed before the overdraft existing in the east-side and coastal areas can be overcome.

Southern Central Coast Counties

The coastal portions of San Luis Obispo County are irrigated from their local streams. Two storage projects of the U.S. Bureau of Reclamation provide flood control and irrigation use to supplement existing sources.

In Santa Barbara County the U.S. Bureau of Reclamation has constructed the Cachuma Reservoir on the Santa Ynez River. The water stored is diverted through a tunnel to the coastal area to be used from Goleta to Santa Barbara. It is also planned that part of the storage will be used on lands along the Santa Ynez River and in Lompoc Valley.

The principal streams in Ventura County are the Santa Clara and the Ventura rivers. Like the coastal areas farther south, there are upper valley areas along these streams and a coastal plain. The small summer stream flow makes it necessary to rely on ground water for irrigation.

Ventura River is a principal source of municipal water supply for Ventura and is also used for some irrigation along its course. Storage has been constructed on the drainage area which is used mainly for flood control and municipal purposes.

The Santa Clara River crosses the Piru, Fillmore, and Santa Paula basins before it reaches the Oxnard Plain. The Santa Clara Water Conservation District has spread stream flow since its organization in 1927. The earlier artesian wells in the Oxnard Plain had sufficient pressure to raise water fifteen to twenty feet above the ground surface.

The United Water Conservation District has recently constructed storage on Piru Creek to provide an additional supply for ground-water recharge. This district and the Calleguas Municipal Water District, which includes lands in the southern portion of the county, have been involved in contested procedures over permits for additional unappropriated waters before the State Water Rights Board. The decision of the Board has been appealed to the courts.

Southern California Coastal Areas

These areas comprise the basins of the streams draining into the Pacific Ocean from the Mexican line to Ventura County. As these areas do not extend far inland and have only limited drainage areas of high elevation, their runoff is generally restricted in amount. Runoff occurs mainly during the rainy winter season as the direct result of precipitation during the generally heavy storms which this area receives. There is little accumulation of snow to sustain stream flow beyond the rainy season so that the late summer runoff is very small. This makes the full utilization of such runoff dependent on storage.

Nature has provided large underground reservoirs in this area. The rapid erosion, steep slope, and torrential flow have resulted in extensive and deep absorptive alluvial deposits in the valley portions of these streams. The low flow and much of the flood flow is absorbed in its course over these basins and retained until it may be withdrawn by either natural or artificial means. Among the natural means of withdrawal is return flow by seepage back into the stream channel where the basins may be wholly or partially closed by impervious formations. Pumping from wells is the principal method of withdrawal from such ground-water storage.

The standards of the irrigation practice, in the costs incurred to secure water and the care used in its handling, are higher than those usual in other irrigated areas. As this area is visited by more people from other states than other portions of California, it has come to stand as an example of California practice in the minds of many who are not fully acquainted with the whole state. While the practice here has been distinctive in its methods, it does not represent a major part of the development in the state, as this coastal area includes less than 10 percent of the state's total area irrigated. Areas which have been irrigated have been reduced by the rapid urbanization of lands during recent years.

Following statehood, systems began to be built for the development of areas along the available streams. These were gradually extended as population increased and the results secured created a demand for additional land. By 1870 several ditches were diverting water from each of the major streams and conflicts over the rights to the use of their flow had begun to develop. The

direct connection of this area with the East by the Southern Pacific Railway in 1881 and the Santa Fe in 1885 stimulated the demand for land. General boom conditions prevailed in the late 1880's and continued until checked by the depression of the early 1890's. By this time most of the present canals had been built and were in use. Stream flow was fully utilized by 1900. More recent expansions have been based generally on further use of ground-water supplies.

An early example of colonization methods is described in a report on Irrigation in the United States by R. J. Hinton, published as a Senate Document in 1891, as follows:

"A land sale that took place quite recently in San Bernardino County illustrates the progress of the small farm. At this sale, conducted by a company which has constructed irrigation works in a field heretofore regarded as unpromising, over 8,000 acres of land were disposed of at an average rate of $66.34 per acre. Of this land 2,000 acres was disposed of in ten-acre lots; nearly 1,400 acres were sold in twenty-acre parcels. A few other sales were made at 40, 50, 60, 70, and 80 acre divisions. Two bodies of 700 acres each and one of 170 acres were sold to speculative parties. Nearly all the lots sold above twenty acres each were purchased by Eastern people. The California purchasers, who knew the advantages of compact village life and horticultural settlement, contented themselves with smaller purchases."

The importance of reducing losses in the conveyance of water was early recognized. By 1880 concrete construction had begun to come into use and James D. Schuyler reported to the State Engineer that there were 17,000 feet of concrete ditch used by the Lake Vineyard Association diverting from the Arroyo Seco and three miles of concrete pipe along the cliff in a diversion from the San Gabriel River to San Dimas. Lining canals with cobbles six to eight thick, set in lime mortar with a small amount of cement and covered with a plaster coat, was also used. By 1888 the Pomona Land & Water Company was reported to have had forty-five miles of concrete pipe eight to twenty inches in diameter. A two-inch cement-plaster lining on a trimmed-earth ditch was in use by 1885. By the early 1890's concrete pipe was in extensive use in many of the southern California systems.

An early use of ground water for irrigation reported in the Coastal Basin was that of Governor Downey in 1868. This was a shallow artesian well. Others followed rapidly in this area, with later wells penetrating deeper strata. Wells were also developed in other artesian areas. By 1880 about 400 artesian wells, having diameters from two to eight inches and depths from 80 to over 400 feet, irrigating 18,000 acres, were reported by the State Engineer. In a report in 1880 to the State Engineer, James D. Schuyler, then one of his principal assistants and later a prominent consulting engineer, stated that decayed tule roots and pine wood were taken from the last sixty feet of a well 410 feet deep in the San Bernardino basin. Mr. Schuyler also quoted without comment a local engineer to the effect that "Small fish (suckers) two to four inches in length, resembling those found in the mountain streams, were occasionally ejected from this well." This may be the beginning of the often-repeated claims for underground streams tapped by wells. However, the existence of such streams containing fish has not, as yet, been established to the extent that the Fish and Game Commission has attempted to take jurisdiction and enforce closed and open seasons on the pumping draft.

A feature of the early ground-water conditions in this area was the cienegas. These are moist areas in which ground water is forced to the surface by underground obstructions. The discharge from the cienegas supports the overlying vegetation and, in some cases, provides outflow for other uses. Schuyler in his report to the State Engineer in 1880 describes eighteen cienegas in a distance of eight miles along the rim of the plateau from the

Arroyo Seco to the San Gabriel River, which were supplying water for the irrigation of 3,100 acres. Other similar areas existed on other streams. Schuyler defined cienegas as swampy or boggy ground caused by the rising of subterranean waters to the surface, a spring surrounded by a marsh. These areas have now become generally dry as the result of extensive draft on their sources of supply.

San Diego County

San Diego County differs from the other counties in southern California in having a continuous range roughly paralleling the coast, so that its individual streams have relatively short lengths and limited runoff. The deep pervious basins characteristic of the lower courses of the streams farther north are also generally lacking. Fortunately, conditions for surface reservoirs are more favorable and the regulation of the local streams has been accomplished by surface storage. The total supply available, even with all of the regulation that is feasible, is insufficient for the needs of the local population and irrigable areas.

The rapid growth in the demand for water in the 1940's made it necessary to secure an outside supply. Plans for this had been made in the 1920's. A pipeline to connect with the system of the Metropolitan Water District of Southern California was completed in 1947. This is used mainly for municipal purposes and is described in chapter VII.

A study of the water resources of San Diego County was made in 1935 by the State Engineer and reported in Bulletin 48 of his publications. A total mean annual runoff of about 300,000 acre-feet from all local sources was found, with 85 percent of this occurring above available reservoir sites. Single years were found to have runoffs varying from 5 to 710 percent of the long-time mean. One period of nineteen years, from 1914 to 1933, had a mean runoff of 131 percent of the mean of the forty-seven-year record period and another nineteen-year period, 1895 to 1914, had a mean runoff of only 57 percent of the same mean. The nine years 1895 to 1904 had a mean runoff of only 19 percent of the longer mean.

The first settlement in California was at San Diego in 1769 on the south bank of the San Diego River at the Mission. The mission dam with a tile-lined conduit six miles in length was built and placed in use shortly thereafter. Mission settlements followed at San Luis Rey in 1798 and at Pala in 1815. Irrigated areas were developed slowly until the construction of the Santa Fe railroad to San Diego in 1885 started a growth of boom proportions. This subsided in the depression of the 1890's and was followed by a more steady growth during this century. An irrigated area of 49,000 acres was reported in 1932; while not large in relation to areas on the larger streams of the state, this represented a 95 percent increase over the area irrigated in 1919. The present area irrigated is about 60,000 acres. Much of this area is suburban in type, consisting of small ownerships.

Costs of water for irrigation are relatively high. The average annual use of about 1.5 acre-feet per acre is relatively low. A large part of the avocado production of the state is in San Diego County.

The first major storage construction in the county was the dam on the Sweetwater River, built from 1886 to 1888. The original dam has been raised when overflows have occurred. In 1935 the total reservoir capacity constructed in the county for all purposes was 583,000 acre-feet. The safe annual yield of the water supplies obtainable from these reservoirs was estimated by the State Engineer to be 79,000 acre-feet. This represents over seven acre-feet of constructed storage capacity for each acre-foot of safe annual reservoir

yield. This is an unusually large ratio and illustrates the wide variations in runoff of the streams in this area. The ultimate safe yield of the local supplies when regulated by the full storage construction planned was estimated to be 160,000 acre-feet per year. This is only slightly more than one-half of the total mean annual runoff. This is a relatively low ratio of safe yield to total runoff.

Irrigation from Santa Ana River

The Santa Ana River drains areas extending farther inland than other southern California rivers, so that its valley lands have a wider range of climatic conditions than other adjacent streams.

There are two main basins in the Santa Ana drainage area. The upper basin is formed by the Bunker Hill Dike extending across the valley near Colton. This dike has caused the ground water in the upper basin to rise to the surface. Below the upper basin the river flows in a canyon until its valley widens on the coastal plain. Within the canyon section there are two tributary areas; that of the Chino Basin on the north in the vicinity of Pomona and Cucamonga and the drainage area of San Jacinto River and Temescal Creek on the south. The census of 1939 reported an irrigated area of 259,000 as supplied from the Santa Ana River.

Above Bunker Hill Dike is a large ground-water basin which is the principal source of water supply for the upper canal systems. Artesian wells were used in the earlier developments, followed by pumping in later years. As early as 1905 W. C. Mendenhall in Water Supply Paper 142 of the U.S. Geological Survey concluded that there was an overdraft on this basin. Court decisions have defined some of the rights to the use of these waters and further litigation is in progress.

Lack of suitable sites for surface storage resulted in the spreading of flood waters to increase percolation to the ground water. This practice has been successful. The artificial recharge mingles with the natural recharge and the mingled ground water is used without attempts to distinguish its source.

In the 1870's relatively shallow wells in the lower portion of the valley had sufficient pressure to be used for domestic purposes. In 1892 the Gage Canal secured artesian flows of nearly 700 miner's inches from seven wells about 200 feet deep. In recent years, increased pumping draft has resulted in nearly complete reduction of the rising water during periods of deficient runoff.

The first large diversion was by the Riverside Canal, begun by a New England colony in 1870. This was followed by the Gage Canal in 1885. By 1904 over 50,000 acres were being irrigated from this basin.

The drainage area of the San Jacinto River is a part of the Santa Ana drainage. Diversion for lands near Hemet started in 1885. The Lake Hemet Water Company and the Fruitvale Water Company were the principal surface systems. Ground water has also been extensively used.

In the coastal area of the Santa Ana Basin, the Santa Ana and the Anaheim Union are the largest canals. Ground water is extensively used. This area is now purchasing water from the Metropolitan Water District for recharging the ground water. Charges to meet payments for the purchased water are made in part on the basis of the ground-water draft by each user and in part by taxes.

Irrigation from San Gabriel and Los Angeles Rivers

The San Gabriel River flows across a wide valley in its course from the mountains to Whittier Narrows. The restriction in the valley outlet there resulted in rising water which formed a surface stream until the draft on the

ground water depleted this outflow. Below the Narrows the river crosses the coastal plain in two channels. Like other southern California streams, the summer flow is small. The main use of its runoff is by pumping from the ground water which it recharges.

Storage has been constructed on the upper San Gabriel River for flood control and for municipal use. Only the part of the runoff which would flow across the valley and waste into the ocean is stored. Extensive studies of the basis of operation which would enable such storage to be secured without detriment to the ground-water supply were made by the State Engineer prior to its construction. Additional lower reservoirs have been constructed for flood control.

Irrigation from the Los Angeles River has been closely related to its use by the pueblo and later by the City of Los Angeles. The prior pueblo right to the flow of the river was recognized at an early date. When water was secured from Owens River, the city boundaries were extended to include the lands which would be irrigated until the growth of the city would result in their urbanization. The ground-water storage of the San Fernando Valley is used to regulate both the local and the imported water supplies.

The U.S. Census reported 159,000 acres irrigated in the area served by the combined San Gabriel and Los Angeles rivers in 1939. This includes the area of the coastal plain adjacent to these streams. The irrigated area has been decreasing as subdivisions have replaced agricultural use of land.

Irrigation in Coastal Plain

The coastal plain of southern California extends from the Santa Ana River to the Santa Monica Mountains. It is from fifteen to twenty miles wide and fifty miles long. The surplus waters of Santa Ana, San Gabriel, and Los Angeles rivers, as well as smaller local streams, find their outlets to the ocean across this plain. As a result of its distance from the mountains its alluvial fills are composed of finer materials. This fill contains ground water which was largely under artesian pressure prior to its extensive development. Much of the agricultural development in this area is being replaced by municipal and industrial expansion.

The State Geologist in his report for 1853-56 gives the log of an artesian well in Los Angeles. This well was four hundred feet deep. He recommended that the county should drill trial wells as a guide and aid to private drilling and predicted that artesian flows would be secured over the coastal plain at depths of four hundred feet.

The initial area in the coastal plain in which artesian flows could be secured extended along the coast for forty miles with a width of two to twelve miles. The drilling of artesian wells became extensive about 1870. Schuyler reported 550 such wells in 1879, with an estimated total discharge of 55 second-feet. The largest single well was the Burlingame near Compton, which had a flow of 1.7 second-feet. The depths varied from 50 to 550 feet, with the larger number 150 to 200 feet deep. Pressures were decreasing by 1879 and some wells flowed only in the Spring following the winter period of reduced draft.

In 1904 Mendenhall reported over 8,000 wells in the total coastal plain. About one-third of these were domestic wells of small draft. There were about 2,500 flowing wells in 1904, with an estimated total discharge of 300 second-feet. The area in which artesian wells could be secured had shrunk from 290 to 190 square miles as a result of this draft and a sequence of dry years. Continued draft resulted in further shrinkage of the artesian area. By 1928 artesian flow had become negligible and practically all draft was by pumping.

Irrigation in the Imperial Valley

In building its delta at the head of the Gulf of California, the Colorado River cut off a former inland sea, leaving much of its area below sea level. Occasionally the river has broken through its own delta deposits and discharged part or all of its flow into this depression, creating an inland lake. This present lake is the Salton Sea. Probably for several hundred years prior to the present century, such breaks of the Colorado River to Salton Sea have closed themselves and the river flow has reverted to the Gulf of California. The channels of such silt-laden streams are never stable on their deltas.

In 1853 Blake gave the name of Lake Cahuilla to the maximum stage of this lake. Its shore lines indicate that it had an area of about 2,100 square miles. It was dry in 1853. C. L. Cory quotes old-timers' reports that there was water in Salton Sea at several times prior to 1900. In 1891 the flow of the Colorado River was very high and overflow into New River occurred. Salton Sea reached to Salton station on the Southern Pacific Railway.

The irrigation of the Imperial Valley was first proposed by Dr. O. M. Wozencraft, who attempted to secure funds for the construction of a canal during the 1850's. Results to 1880 are summarized in a report of the State Engineer as follows:

"For many years the utilization of water from the Colorado River on the great desert of the same name, has been periodically and often brought to public attention, and Congress had been urged to grant concessions in various forms, or make appropriations to carry out certain projects for the purpose, as public works. The original idea seems to have been to turn the waters of the river into the great basin, making it a lake, and thereby affecting such a change of climate as would render the country around it habitable and cultivable. Then it was afterward proposed simply to take out waters in an immense canal for irrigation of extended areas of the desert land."

The idea of changing the climate by producing evaporation has been frequently advanced. There is direct evidence that this result does not follow insofar as the Imperial Valley is concerned. Water has now been diverted into this desert area for over fifty years. The evaporation either from Salton Sea or from the lands irrigated has exceeded 2,000,000 acre-feet per year, yet the rainfall remains as it was prior to development at an average of about two inches per year. While this increase in the supply of moisture in the atmosphere cannot be retained permanently in the air and must increase precipitation somewhere by an equal amount, its return is so widely distributed or so distant from its point of origin that its effect has not been traced.

While all early plans for the irrigation of the Imperial Valley recognized the desirability of constructing all of the works required wholly within the United States, they also recognized the physical difficulties of such construction and selected canal locations in Mexico. This condition is the result of the sand ridge on the west of the river. To secure economical construction, it was necessary that the main canal should pass around the south end of the sand ridge in Mexico rather than through it in the United States. The present All-American Canal became possible only after the early development had created the present values in the Valley and when interest-free funds for its cost had become available from the federal government.

The California Development Company constructed a canal into the Imperial Valley in 1900-1902. A concession was secured from the Mexican government and the portion of the canal in Mexico was built by a Mexican subsidiary of this company. Water was sold to entrymen on the public lands in the Valley with the local distribution systems handled as mutual water companies.

The increase in the area irrigated in the Imperial Valley was rapid. Twenty-

five thousand acres were reported as irrigated in April 1903 with an increase to 100,000 acres, mainly in grain, by the following winter. This rate of increase is a record for any project in this country. For any new project, no matter how active the land demand may be or how attractive a particular project may appear, the settlement and development that can be directed to any one locality has seldom resulted in an increase in irrigated area in any one year of half of this rate. The irrigation of 200,000 acres was reached in 1910, 300,000 acres in 1916, and 400,000 acres in 1919. In recent years the net acreage irrigated has generally been nearly 500,000 acres.

The most spectacular part of the history of the Imperial Valley has been its struggle against the inflow of flood waters from the Colorado River. With the river flowing on a ridge higher than the valley, any water escaping from the river, on its western bank, has a natural gradient through the valley to Salton Sea. With the easily erodable banks and bed consisting of river silt, any break may soon enlarge itself so that its closure becomes difficult and expensive. When to these physical features were added the complications of doing work in Mexico for the benefits of lands in the United States and the limited financial resources usual during the development stages of such projects, breaks and difficulties in their closure were almost certain to occur.

Difficulties in securing a sufficient diversion through the then available headworks during 1903 and 1904 led to the construction of an uncontrolled dredger cut into the canal from the river about four miles below the international boundary. A flood in December 1904 enlarged this cut by erosion and by August 1905 the entire river was passing through what had been the dredger cut and was flowing through the Imperial Valley to Salton Sea. The main part of this flow was carried through the New River and the Alamo River channels. These eroded rapidly with their grade recession working back at a rate which would, if continued, reach the river and make closure very difficult if not impossible. To protect its lines, which were being submerged by the rise of Salton Sea, the Southern Pacific Company undertook to close the break. Its efforts in 1905 were not successful but closure was accomplished in November 1906. A second break occurred in December 1906 which was closed in February 1907.

The efforts to control the river and to close these breaks represent one of the engineering epics of the west. However, these closures did not end the problem of keeping the Colorado River out of the Imperial Valley. The California Development Company had been taken over by the Southern Pacific Company. Much additional work was needed to prevent further inflow. In 1916 a flood of 200,000 second-feet occurred on the Colorado River but further breaks were avoided. Continued work in Mexico was needed to divert the river away from channels leading to the Valley.

In 1904 Salton Sea had been practically dry at elevation 273 feet below sea level. It rose rapidly after inflow from the Colorado River began. When the break was finally closed in 1907, Salton Sea had risen to elevation 185 feet below sea level. It has been estimated that about 22,000,000 acre-feet of Colorado River water reached Salton Sea from 1904 to 1907. Sixty-seven miles of Southern Pacific main-line track had to be moved to keep above the Sea.

With direct inflow from the Colorado River shut off in 1907, Salton Sea lowered steadily to about elevation 240 below sea level in 1924. In recent years, waste and drain waters from the Imperial and the Coachella valleys have maintained the Sea with some rise as the present inflow and evaporation seek a balance.

Levees built in Mexico were not a permanent solution for the control of the Colorado River. The continued deposits of silt, with the resulting rise of

the river channels, meant an increasing menace from further breaks. Permanent flood control required storage. Such control was secured with the construction of Hoover Dam.

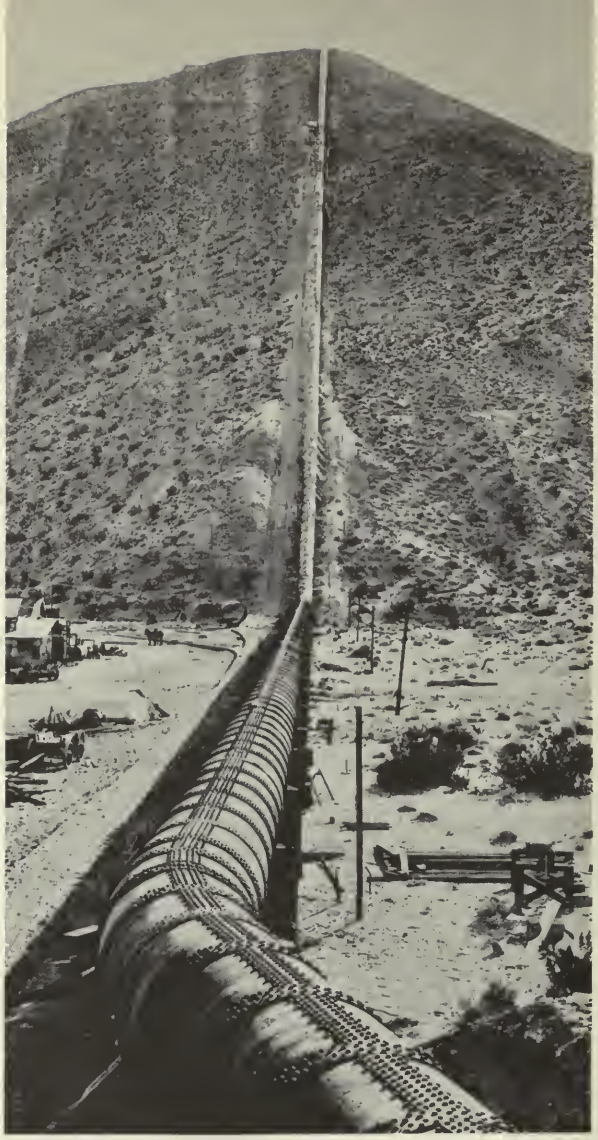
The difficulties which the constructing companies had encountered resulted in a desire by the landowners in the Valley to own and operate their entire canal system. The Imperial Irrigation District was organized in 1911 with an included area of 523,000 acres. This area has since been increased to over 600,000 acres. The district voted bonds and in 1916 acquired the properties which the Southern Pacific Company had taken over from the California Development Company. By 1923 the district had also acquired the mutual water companies within its area so that it owned and operated the entire canal systems serving its lands. It has also constructed an extensive drainage system and has developed and serves power within its area.

The complications of doing work in Mexico continued after the Imperial Irrigation District had acquired the works there. A final solution of this situation could be reached only by the construction of a canal within the United States. Such a canal was authorized in the Boulder Canyon Project Act. The All-American Canal was completed in 1940. It extends to the Coachella Valley for irrigation there.

Irrigation in the Palo Verde Valley

The Palo Verde Valley comprises about 100,000 acres adjacent to the Colorado River near Blythe. The first water appropriation for this area was made in 1877 and is the earliest acquired right to the use of waters of the Colorado River in California. Settlement began prior to the flood of 1905 which destroyed much of the then improvements. In 1908 the Palo Verde Mutual Water Company took over and improved the canal system. While the entry of public lands proceeded rapidly, the irrigated area increased slowly until a railroad was constructed into the valley in 1915. The flood of 1922 broke the river levees and did extensive damage in the valley. In 1923 the Palo Verde Irrigation District was organized under a special statute passed for its use. This district took over the irrigation system, the river levees, and the internal drainage system. In the 1930's the total cost of these functions was greater than the lands could meet and refinancing, through the Reconstruction Finance Corporation, was secured. Since the completion of Hoover Dam, the flood menace has been removed and the flow of the river regulated. The area irrigated has increased, with greater crop diversity.

The experience of the Palo Verde District illustrates the uncertainties that result when nature's balance for one set of conditions is disturbed by a change in some of its element. Prior to construction of Hoover Dam, this district diverted successfully without a diversion dam, as the silt-laden river maintained its channel at the point of diversion high enough to enable this to be done. Following storage at Boulder Canyon and later at Parker Dam, the removal of the silt load resulted in the clearer water eroding the channel at the point of diversion so that the required flow could no longer be secured. To offset this condition, a diversion weir was required and has been constructed.



CHAPTER VII

Municipal Water Supply

The municipalities in California have secured their water supplies from surface streams or ground waters, depending on the particular sources more economically available to each city. This is the same practice followed by cities in other states. In the selection between these types of water supply, the results in California are not distinctive.

The principal items in which the municipal water systems in California differ from those in other states are the seeking of water from sources which are usable without purification and the long distances it has been necessary to convey water to the larger cities in order to secure an adequate supply for their needs. Many California towns secure their water supply from local wells or streams at generally moderate costs and without material complications. The outstanding systems are those serving the three major metropolitan areas in the state.

Another feature of the municipal water-supply systems in California is the extent to which it is necessary to provide storage in order to maintain adequate service during periods of deficient runoff. Such cyclic storage may be secured by means of large-capacity surface reservoirs or by the use of the

naturally available storage in ground-water basins. The water supplies used by municipalities are no more variable than those used for other purposes but the greater damage resulting from a shortage in a municipal supply makes it necessary to make additional provision against its occurrence.

California cities have had similar experience with private and municipal ownership of their water systems to that in other states. Earlier developments were largely by private companies. Later, many cities have taken over this service. While there are still many private systems in the state, the larger number are municipally owned. There is a trend toward the acquirement of the present private systems by the municipalities they serve. Municipal water supplies require such careful protection of their quality that there is support for their ownership by those served in order that matters affecting health may not be complicated by separate identity of the owners of the systems and the users of the water.

For those municipalities in California which have to secure their water supplies by bringing them in from distant sources, it is particularly necessary that plans be made well in advance of actual needs. However, the necessarily high costs of such projects require that their construction be deferred until the growth of population supplies the financial resources with which to build them. These conditions require that particular care be used in forecasting the growth of population and demand.

Population forecasts can be made with reasonable assurance that the actual departures will not be too large in the older and more stable communities in the eastern states. In California there has been much less background on which to base such forecasts. While population growth and water demand fell behind that expected during the earlier 1930's, the rapid increase during and after World War II has resulted in many present needs being ahead of the earlier forecasts.

Many municipal water supplies in California are used without purification. Ground waters in the inland valleys have been delivered into the distribution lines without storage and with little treatment. The desire to secure water which would not require treatment has been a major factor in the support for projects to bring water from undeveloped mountain drainage areas. Such sources are now becoming subject to increasing opportunities for pollution and the treatment of municipal supplies in California has become more extensive as the population has increased.

Early California Systems

The first domestic water-supply system in California was probably the publicly owned Zanja Madre, built in Los Angeles soon after the establishment of the pueblo in 1781. The first system selling water in the mining areas may have been the New England Water Company at Columbia in 1853. This company piped water a distance of a mile from a spring to a tank in Columbia. Water was carted through the town and sold for five cents per bucket. The original wooden pipe was replaced in 1856 with iron pipes and pressures increased so that fire streams could be thrown to heights of eighty feet. In 1859 Stockton granted a franchise to the use of water from the city's artesian well. This deeper ground-water supply was described in 1874 by the Stockton Board of Trade as "never affected by drouth or floods, and retains its limpid purity during all seasons of the year."

Water works were installed in other San Joaquin Valley towns as soon as they were justified. A system in Hanford, built in 1881, advertised in 1885 that baths, both hot and cold, were available, for those whose residences were not connected to the system, at twenty-five cents or five tickets for one dollar, on application to the engineer. The company stated:

"The Tank House which supports a tank of 26,000 gallons capacity and contains Bathrooms and Sleeping apartments, is complete in every respect, and is considered to be one of the finest and most substantial buildings of the kind in Southern California."

The Tulare City Water Works had five miles of mains in 1885. Their monthly rates were adjusted to the services of the times, as shown by their advertisement:

Tenement houses not more than 5 persons	$ 1.50
each additional person	.25
Small families - not exceeding 4 persons	1.50
each additional person	.25
Saloons	3.00
Public Water Closet - one seat	1.50
each additional seat	1.00
Grass plots, Flower Gardens, by yearly contract, per square yard	½c

The more spectacular municipal water systems in California are those supplying the three principal metropolitan areas of Los Angeles, San Francisco, and the east side of San Francisco Bay. Each of these systems justifies a review of its history and its accomplishments.

Water Supply of San Francisco

Situated on the end of the peninsula, San Francisco has had to go outside its own locally tributary drainage areas to secure water for its municipal needs. This was done relatively early in the history of the city with the distances from which water was brought being increased until the city obtained, from Sierra sources, a supply adequate for its demands.

The first water used in San Francisco was secured from small springs and wells within the city and from supplies brought in from Marin County by boat. These waters were delivered by wagon and sold by the bucket or barrel. The first water system was that of the San Francisco Water Works in 1857 which developed a small supply on Lobos Creek within the city limits. The Spring Valley Water Works secured a franchise from the Legislature in 1858 and distributed water from Islais Creek in 1861 and from Pilarcitos Creek in 1862. The latter supply included a reservoir and a thirty-two-mile conduit to the city. Other dams on the peninsula were constructed from 1867 to 1890.

This system was expanded in 1875 by the purchase of rights and lands on Alameda Creek. The first pipeline from this source was completed in 1888. Draft on wells in the Livermore Valley began in 1898. The Calaveras Dam was completed in 1925.

Litigation between San Francisco and the Spring Valley Water Company was extensive. Beginning in 1880, the rates were determined by the Board of Supervisors until jurisdiction was placed with the California Railroad Commission (now the Public Utilities Commission) in 1911. Frequent suits were brought against the rates fixed by the supervisors.

It was recognized at an early date that eventually the growth of San Francisco would require a water supply in excess of those available near San Francisco Bay. Various projects were proposed for such outside supplies. Diversions from Clear Lake and Lake Tahoe were investigated in 1872. In 1894 the city called for offers for outside supplies and received seven proposals, all for Sierra sources.

The city finally selected a water supply from the Tuolumne River, using storage at Hetch Hetchy Valley and Lake Eleanor. The Hetch Hetchy reser-

voir site was in the Yosemite National Park and its use required the consent of the federal government. In 1908 the Secretary of the Interior granted a permit for such use. As a permit granted by one Secretary might be revocable by his successor, the city sought title to the lands to be used through an act of Congress. Attempts to secure such an act resulted in an extensive and bitter contest between the city and the lower users on Tuolumne River and groups which were referred to as the "nature lovers." Congress passed the Raker Act in 1913, giving San Francisco the rights of way it sought, subject to various restrictions on their use. The prior rights of the Modesto and Turlock irrigation districts were to be recognized, roads were to be built in the Park by the city, and the use that might be made of any power that might be developed as a part of the project was restricted.

San Francisco accepted the terms of the Raker Act and began the construction of the project. Work continued for twenty years with the first delivery to the city in 1934 at a total cost to that date of about $80,000,000. The portion of the project in the Sierras was built first so that revenue from power could be secured while the pipelines across the San Joaquin Valley and tunnels in the Coast Range were under way. Throughout this construction period the project was under the direction of M. M. O'Shaughnessy, the City Engineer.

Prior to the completion of the Hetch Hetchy system, San Francisco had acquired the property of the Spring Valley Water Company in 1930. The bond issue for this purchase was $41,000,000. Since 1934 the city has operated the combined local sources and the Hetch Hetchy supply to meet its requirements. The Hetch Hetchy supply is brought into the local system by pipelines across and around the southern portion of San Francisco Bay.

The city has reached agreement with the Modesto and Turlock irrigation districts and is now proceeding jointly with these districts and the United States Army Engineers on an expanded development on the Tuolumne River for flood control, additional water, and power.

The area of San Francisco is limited by its location and the development of other cities on the Peninsula. Its present water supply exceeds its own present needs and water is sold to other water systems around the Bay. San Francisco's ultimate supply when its Hetch Hetchy system may be fully developed will also exceed its own ultimate needs. Terms for the delivery of water to outside agencies on a long enough time basis to justify the construction of facilities to provide additional Hetch Hetchy water are under discussion between the interested parties.

Water Supply of the East Bay Area

The early municipal water systems for the communities on the east side of San Francisco Bay used various local sources distributed by several separate companies. These early companies later were combined in the East Bay Water Company.

Local well fields were developed and storage constructed on local streams. The ground-water supplies were limited. Lake Chabot was built on the lower San Leandro Creek in 1874, the upper San Leandro and the San Pablo reservoirs were constructed later. Growth in demand taxed the supply available from these sources and it was generally recognized that an outside supply was required. Restrictions on use were imposed in 1918 during a period of deficient runoff.

The areas served preferred to have their municipal water service under public ownership. The division of the area into several separate municipalities made the problem of organization for this purpose more complex than for areas entirely in one city. To meet this condition, the Legislature passed

a municipal utility district act under which such utility districts could include lands in separate municipalities and unincorporated areas for public services, such as water, sewerage, or power, without affecting other municipal functions.

As first organized in 1923, the East Bay Municipal Utility District included nine cities. Additional areas were added so that the area included by 1943 was 187 square miles, serving a population of about 725,000.

Soon after its organization, the East Bay Municipal Utility District employed A. P. Davis, formerly chief engineer of the U.S. Bureau of Reclamation, as its Chief Engineer. Investigations were made of several outside sources of water supply, including the Eel, McCloud, American, Mokelumne, and lower Sacramento rivers, and also of joining with San Francisco in their Hetch Hetchy project on the Tuolumne River.

Much discussion arose regarding the relative merits of "mountain" supplies, such as the Mokelumne, and of lower river supplies requiring filtration, such as diversion from the Sacramento River below Sacramento. The East Bay Water Company proposed to augment its supply from the latter sources. Hearings on these issues developed much heat and some light on the relative safety and costs of such alternate sources and the extent of their purification that would be required.

Joining with San Francisco was advocated by many in the Utility District. At the time the district plans were being made, there were uncertainties regarding the time when the Hetch Hetchy project would be completed, what its final cost might be, and the amount of the supply of water it might have available for East Bay areas. The need for additional water in the East Bay was urgent and it was felt that the time required to determine these uncertainties was not available. The East Bay District completed its own project five years before Hetch Hetchy water was delivered to San Francisco. In 1931-32 the East Bay District supplied water to San Francisco to meet a shortage in their supply until its own project was completed.

As a result of its investigations the East Bay District selected the Mokelumne River as the source of its additional water supply. Storage was built at Pardee Reservoir on the lower Mokelumne River and water was conveyed by gravity flow in a pipeline to the East Bay area. One pipeline was constructed initially, with a second line constructed in 1947 when a larger capacity was required. A bond issue of $39,000,000 was voted for the cost of the initial Mokelumne supply. In 1928 the properties of the East Bay Water Company were purchased at a cost of about $25,000,000. The first Mokelumne water was delivered into the East Bay area on June 19, 1929, just in advance of the impending depletion of the local storage supply resulting from a series of years of deficient runoff and increasing use.

The project of the East Bay District was selected, built, and water delivered within six years of the time of the organization of the district. Its costs were within the estimates on which the bond issues were based. This record reflects credit on the entire organization of this project. The Utility District has continued to supply the municipal water needs of its area. In recent years it has also been used as the agency to collect and treat the sewage from the main portions of its area. Such sewage treatment was required to reduce pollution in San Francisco Bay.

By 1955 the district included thirteen incorporated cities and unincorporated areas having a total area of over 215 square miles. The net value of its plant and properties exceeded $125,000,000. Its mean daily water consumption had increased from 45 million gallons per day in 1940 to 121 million gallons in 1955. In 1958 about $250,000,000 in bonds were voted to develop, transport, and distribute an additional supply of 125 million gallons per day from the Mokelumne

River. The estimated ultimate area of the district is four hundred square miles, having an expected population of 2,600,000.

Water Supply of Los Angeles

Los Angeles was founded as a Spanish pueblo in 1781 with an initial area of one square league. The first water system was the publicly owned Zanja Madre extending to the old Plaza. The Los Angeles River continued to be the source of the city's water supply until Owens River water was delivered in 1914. The pueblo of Los Angeles has pueblo rights to the use of all of the water of the Los Angeles River for municipal purposes. These rights have been subject to extensive litigation. This water system has continued to be publicly owned, except from 1868 to 1902, when it was operated under franchise by a private company.

It was recognized by 1900 that the population would outgrow the locally available water supplies and a search was made for other sources within nearby areas. These were all limited in amount or were being used by others. Owens River was a distant but possible source of supply.

Owens River drains an enclosed basin along the eastern slope of the Sierras. Its unused runoff maintained Owens Lake and supplied its evaporation. The valley lands had been settled and irrigated, largely for stock raising, prior to the entrance of Los Angeles into the valley.

In 1905 the city acquired an option on the riparian lands along forty miles of Owens River and bonds were voted for their purchase. In 1907 bonds were also voted for the construction of an aqueduct to convey Owens River water to Los Angeles. Construction was begun in 1908 and was completed in 1913, within both the planned time and the estimated cost. While this project has been exceeded in cost and size by some other western projects, at the time it was built, it was an outstanding undertaking.

The relationship of the city and the landowners in the Owens Valley was a source of continuous friction from the early days of the project. Whenever changes are produced in any area which require relocation of existing populations, some hardships are unavoidable. The acquirement of rights of way for present-day freeways illustrates individual damages which cannot be adequately compensated by money payments. Initially, the city acquired the lands below its point of diversion which might be affected by its project. Later, to secure additional water, it acquired irrigated areas above its diversion and transferred the waters acquired with these lands to the aqueduct. Still later, when years of deficient stream flow resulted in shortages in the supply, wells were used to secure ground water from under the purchased lands. Congress made the public lands in the valley available to the city in 1906, and by 1916 the city had acquired 125,000 acres of privately owned lands.

Having bought nearly all of the agricultural land in the valley and retired it from irrigation, the local towns felt the effect of the reduction in their volume of trade. Local feeling in the valley against the city grew over the years, until it reached a point where the bitterness engendered clouded the issues and prevented reasonable adjustment of differences. Lawsuits with valley interests were generally decided unfavorably to the city. Dynamiting of the aqueduct occurred.

The city expressed its willingness to purchase the lands in the towns but questioned its legal right to acquire lands not directly useful in providing water for the project. Means for such purchases were eventually found. The city then acquired practically the entire valley insofar as it was affected by the use of the local water by the city. The prices paid were generally reasonable in the early purchases at the time the aqueduct was constructed and

Los Angeles Department of Public Service photograph

Hauling with Tractors During Construction of Owens River Aqueduct, 1906-13
From Report on Construction of Los Angeles Aqueduct, 1916

gradually increased until the cost of much of the land and town properties exceeded what their values would have been if the city had never entered the valley. In terms of money the city's treatment of the valley owners was liberal. Eventually the animosities of the earlier years have been largely overcome.

After the city had acquired the lands and towns, other factors began to enter. The adjacent Sierras became an extensively used recreational area, initially for summer vacationists and later for winter sports. Tourists created business for towns in the valley. To meet this demand, the city has leased or sold town properties with reservations relating to water. Lands have also been leased for farming where this could be done without injury to the city's water supply. The local towns have largely regained or exceeded the volume of business on which they existed prior to the start of the city's project.

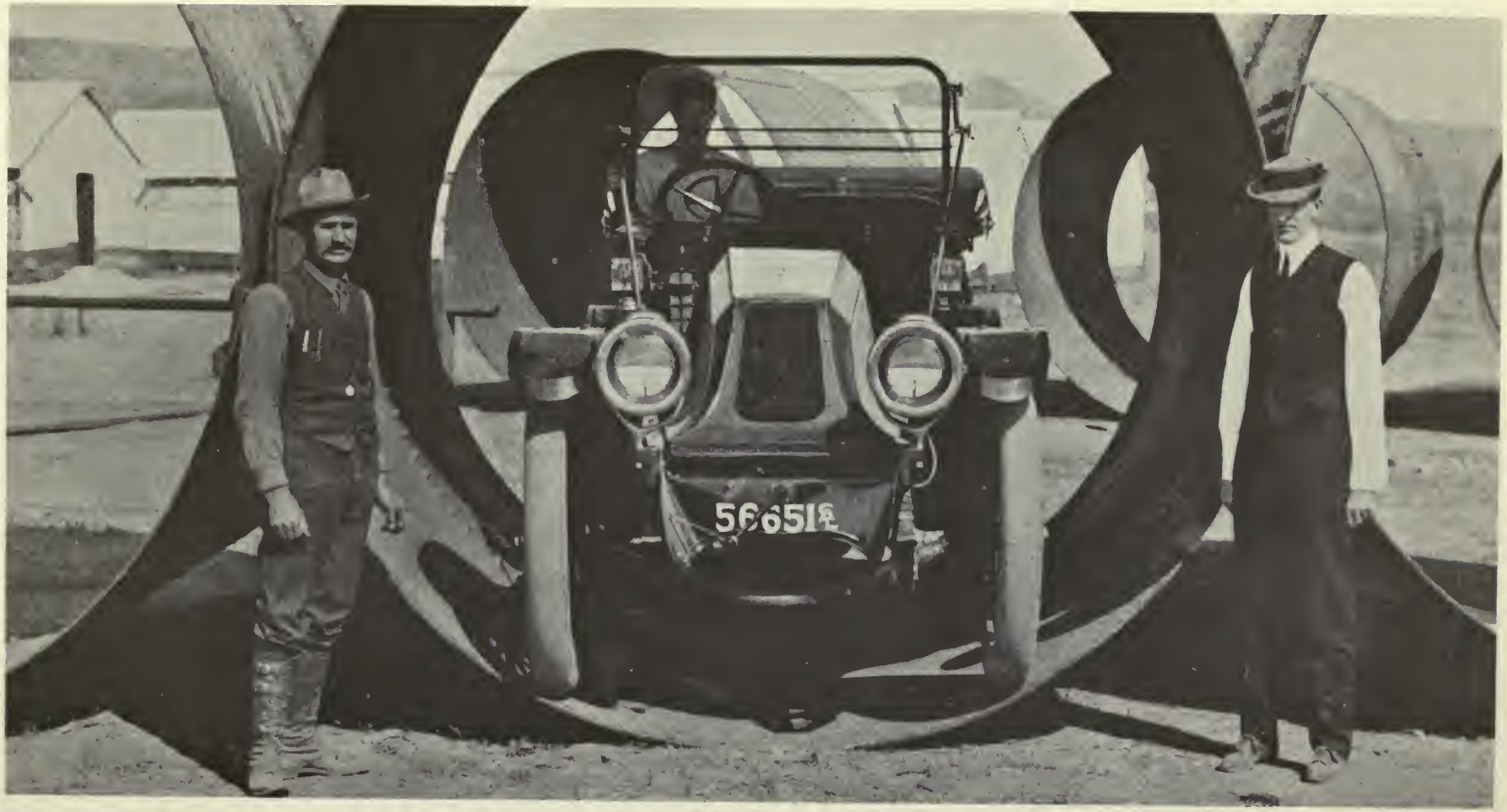
An unusual type of litigation resulting from the city's operations in the Owens Valley has been the suits involving Owens Lake. Owens Lake was the evaporation pan for the surplus flow of Owens River. Such evaporation over the ages had concentrated the water in the lake and deposited valuable brines in its bed. After diversions by Los Angeles began, the reduction in inflow resulted in the lake becoming dry. This condition made it feasible to recover valuable products from the underlying brines and chemical works for this purpose were constructed and operated. As Owens Lake had been navigable in its early condition, the land in its bed belonged to the state. The chemical plants were operated under lease from the state and paid royalties on the products removed.

In 1938 the runoff of Owens River exceeded the diversions to Los Angeles and water again reached Owens Lake. This inflow diluted the brine then being recovered. Suits for damages were brought by the owners of the chemical works and by the state. The state's claim was based on the reduction in its royalties. Damages were awarded against the city because it had not diverted the entire flow of Owens River in 1938.

To supplement the water supply obtainable from the Owens Valley, Los Angeles constructed a tunnel into the Mono Basin. Such Mono waters, when delivered into the Owens River drainage, are carried in the Owens River to the diversion by the Owens River Aqueduct. Storage has also been constructed at Long Valley on Owens River to give more complete regulation of the flow of both the Owens River and the Mono Basin water. The first diversion from the Mono Basin was in 1940. Mono Lake is an enclosed lake in which inflow becomes evaporation from the lake. As the water in Mono Lake is too highly saline to be usable, the Mono Basin diversion is made by a canal intercepting the major tributaries before they enter the lake.

Even with full use of its local sources and the water it could secure from Owens River and Mono Basin, it was recognized that the growth of Los Angeles would require an additional water supply. The only available sources were to go farther along the eastern slope of the Sierras to the Walker River, to the upper areas of some of the San Joaquin Valley streams, such as the Kern River, or to the Colorado River. The first two of these possibilities would involve many water-right complications and provide only limited water supplies. Attention was directed toward the Colorado River.

Investigations of the routes by which Colorado River water might be brought to the southern California coastal area were begun by Los Angeles in 1923. The Boulder Canyon Project Act was passed in 1928 and work on Hoover Dam was started in 1931. Hoover Dam could provide the large supply of power that would be required to pump the Colorado River water so that it could be brought to the coastal area through tunnels of practicable length.



Los Angeles Department of Public Service photograph

Illustration of Size of 10-Foot Diameter Pipe for Soledad Siphon on Los Angeles Aqueduct, Constructed 1906-13. From Report on Construction of Los Angeles Aqueduct, 1916

While the main features of a Colorado River Aqueduct were worked out from the investigations made by Los Angeles, it had been recognized that other adjacent areas had an equal or greater need for additional water and that the project should be carried out by an organization which included all benefiting areas. For this purpose the Metropolitan Water District of Southern California was organized. This district now includes eighty-five incorporated cities and much unincorporated area, with a population of over 7,000,000. The Colorado River Aqueduct was constructed by the Metropolitan District and began delivery of water in 1941. As the Colorado River Aqueduct is a part of the comprehensive development of the Colorado River, its discussion is included in chapter XII with other multiple-purpose projects.

No account of the water supply of Los Angeles would be complete without a reference and a tribute to William Mulholland. He began as a laborer for the Los Angeles City Water Company in 1878. After 1902, when the city took over this company, he advanced until he became the manager of the system. In the fifty years of his active service, Los Angeles made a growth that is outstanding even by American standards in which rapid growth has been usual. Throughout this period the water supply of the city kept pace with its demands. This resulted from Mulholland's foresight in planning and securing additional sources of water supply and from the leadership he provided in securing support for undertaking the projects required. The willingness of the city to venture into these fields was due largely to the confidence of its people in the ability and integrity of Mulholland. He met the failure of the St. Francis Dam with characteristic courage, assumed full responsibility for it, and took a leading part in the settlement of the resulting damage claims.

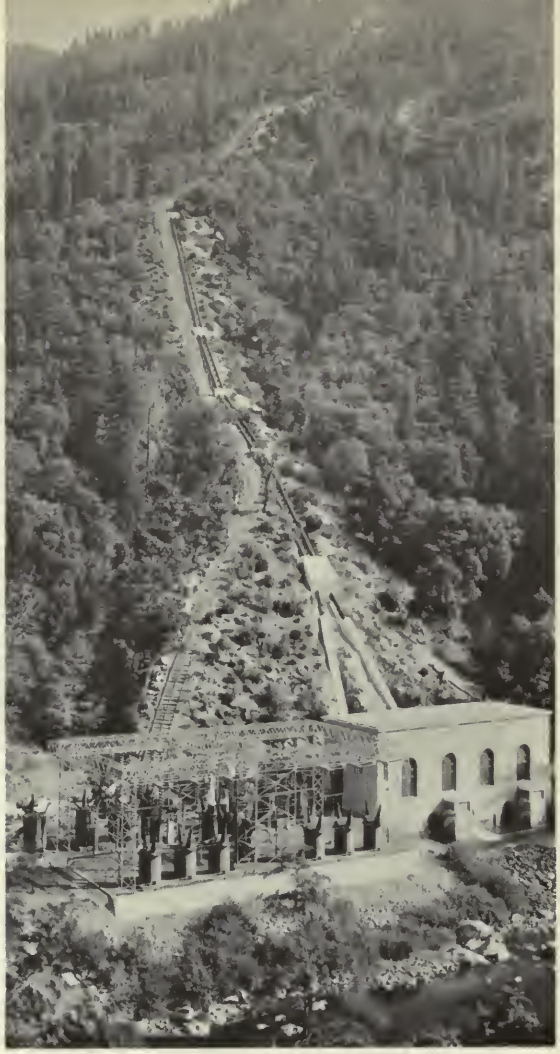
The elevation of the Owens River Aqueduct made available power sites along its route. These were used to develop power. This power has been augmented from other sources and Los Angeles now operates the largest publicly owned power system in the state. Its combined water and power systems are now operated by its Department of Water and Power.

Other California Municipal Water Supplies

San Diego developed its local water supplies to meet its needs until its increase in use made it necessary to secure additional water. Such a need had been foreseen and the city had secured recognition of a right for it to secure Colorado River water. It had been planned to take the Colorado River water from the canal of the Imperial Irrigation District, but the urgency of the need, when it arose, resulted in its being secured by a conduit from the system of the Metropolitan Water District. The first conduit was built in two stages and a second conduit has been constructed. The San Diego County Water Authority was created to include all areas in San Diego County receiving Colorado River water.

Sacramento, to date, has received its water supply from the adjacent Sacramento River. Chlorination began in 1915 and a complete filtration plant began operation in 1924. This is the largest municipal supply used in California which has the extent of pollution that occurs in the Sacramento River. The Sacramento Municipal Utility District was organized to develop power on the upper drainage area of the American River. This district includes areas outside the City of Sacramento. Its project is under construction.

Fresno has secured its municipal water supply from wells within the city. The earlier public-utility system was acquired by the city and has been expanded to meet the city's growth. The original ground-water supply has been increased by the percolation from the canal system and irrigated lands adjacent to the city. Recently the city has been seeking an outside source of supply.



CHAPTER VIII

Hydroelectric Power

California has the requirements for the development of large amounts of hydroelectric power. These include mountain ranges of sufficient height and steepness of slope to provide the fall required. The mountains also receive their larger rates of precipitation on their higher elevations, so that runoff is available through a relatively large total head above the valleys. The principal disadvantage is the seasonal character of the precipitation and runoff, which results in a relatively small low-water flow with a corresponding need for large amounts of storage. Some storage sites are available at elevations where the water stored can be used through total drops as large as 5,000 feet. Single-head plants with drops as large as 2,500 feet have been built.

Development of hydraulic power in California divides itself into two natural periods. One of these is the early period when the water power produced was used directly without generating electric power. The other is the period since electric energy has been transmitted to distant markets. Practically all water power now generates electric power, so that the term hydroelectric power is the only one now needed in discussions of power produced from the energy of falling water.

California also has a well-diversified power demand which results in a relatively high-load factor for those power systems which serve large areas. Use of power for irrigation pumping occurs in the summer months when the general lighting load is below its winter peaks.

Per capita consumption of power increased over fourfold from 1910 to 1945. This, with the rapid increase in population, resulted in rates of increase in the power demand that required rapid expansion of power-generating facilities. This, in turn, resulted in the combination of the many smaller separate power companies into two main privately owned systems, serving the northern and the southern portions of the state, in order to provide the strength to finance such expansions. These companies, together with the publicly owned systems, met the demands for power and provided continually increasing amounts of service. The development of hydroelectric power in California has been as outstanding as the projects for other types of the use of water. Practically every stream of major size in California now has one or more hydroelectric plants along its course.

The capacity and output of power plants may be expressed in terms of kilowatts or of horsepower. Present practice for hydroelectric plants generally uses the kilowatt. One kilowatt is equal to 1.3414 horsepower and one horsepower is equal to 0.7455 kilowatts.

Early Uses of Water Power

Among the first users of water in California were sawmills. Sutter had a mill before constructing the one at Coloma in 1848 which resulted in the discovery of gold. A sawmill using water power was built in 1851 on the Sacramento River just above the mouth of Mill Creek; the logs it cut were floated down the river. Other early water-power sawmills were on the San Joaquin River east of Millerton in 1854 and at Crane Valley in 1860. The first water-power flour mill in the Sacramento Valley was built by General Bidwell in 1853. A similar flour mill was operated at Merced Falls in 1854.

The earlier power plants at the mines used direct rope drives to operate the hoists and other mining equipment. This required locating the power plant at the mine, with a complicated layout of shafts and drives in the mill.

In 1884 Hamilton Smith, Jr., an engineer who had built water-supply projects used for hydraulic mining, predicted in a paper presented to the American Society of Civil Engineers, that when manufacturing in California reached large proportions, the mining ditches would be used to provide the power. These ditches had capacities up to about eighty second-feet and developed heads of 200 to 600 feet. Smith's prediction has been realized, although he probably did not foresee the extent to which such power would be transmitted for use in distant areas.

Early Hydroelectric Power

Electricity had been developed with steam power for lighting or other uses adjacent to the points of generation prior to the first transmission of electrical power for use away from its point of production. Electric lights had been used to illuminate the Cherokee Mine workings in the 1870's. In 1892, 800 horsepower of hydroelectric power were transmitted 28 miles to San Antonio, California. This line carried single-phase current at 10,000 volts. The first three-phase transmission was at Redlands in 1893. In 1894 the Pioneer Water Ditch on Tule River, in addition to irrigation, supplied power for a flour mill and for electric lights in Porterville.

In 1890 a power dam was completed at Folsom on the American River at a cost of $1,000,000. The storage created was soon filled with mining debris, but the head resulting from the height of the dam was used in 1895 to generate power which was transmitted to Sacramento for lighting purposes. This was one of the first plants transmitting electric power to such distances for this

use. This plant had five generators of 1,000 horsepower each. The transmission line consisted of 22.4 miles of double circuit.

One of the earlier hydroelectric power plants was the Colgate plant on the Yuba River, 35 miles northeast of Marysville. It was completed in 1899 and its output transmitted 142 miles to Oakland in 1901. This was the first power delivered in the Bay area from plants in the Sierras. The 40,000 volts at which this power was first transmitted was increased by 1903 to 60,000 volts.

In the early 1890's a Polish prince, Andre Poniatowski, who had come to California, organized the California Exploration Company. This company bought mines and developed power. The Blue Lakes system was acquired, the Standard Electric Company formed, and the first Electra power plant built on the Mokelumne River with a capacity of 10,000 kilowatts. In addition to power service in adjacent mining areas, the plans included transmitting power 110 miles to San Francisco; the first power was delivered there in 1902 at 50,000 volts.

Power Development in California Since 1905

Water Supply Paper 493 of the U.S. Geological Survey by F. H. Fowler, published in 1923, gives much detail regarding the plants which had been built to that date. A report on the water powers of California by Frank E. Bonner, published by the Federal Power Commission in 1928, discusses past developments and future potential power resources. A report by the Federal Power Commission, published in 1953, contains statistical material on the then development and estimates of the potential resources. The results in these reports show the progress that has been made in the actual development of hydroelectric power and the changing estimates of the ultimate resources as more information has become available.

The developments in long-distance power transmission have made the power resources of the Sierra streams available for use in the metropolitan coastal areas. Construction of such hydroelectric plants since 1905 has kept pace with the increase in power demands as it has occurred, subject only to the delays resulting from World Wars I and II. Following each of these wars, the load increased more rapidly than the needed power plants could be constructed and brief shortages resulted.

In 1905 the installed hydroelectric-power capacity in California was about 90,000 kilowatts. By 1910 this had increased to 260,000 kilowatts; by 1920, to 640,000 kilowatts; and by 1945, to 1,847,000 kilowatts. In 1950 there was a total installed capacity of 2,600,000 kilowatts in California, exclusive of Colorado River power. Since 1953 construction of hydroelectric plants has proceeded actively and the completed capacity in 1959 was about 3,500,000 kilowatts.

In 1911 the total hydroelectric power generated in California was 1,068 million kilowatt hours. This had increased to 2,570 million kilowatt hours in 1920 and to 6,772 million kilowatt hours in 1927. In 1945 this total generation was 13,075 million kilowatt hours, and in 1953 it was 15,900 million kilowatt hours. The generation in 1958 exceeded 17,000 million kilowatt hours. These results in recent years do not include the power produced at federal dams on the Colorado River, although this power is used mainly in California. In 1945 these Colorado River plants produced 6,115 million kilowatt hours.

The highest static head of any hydroelectric plant in California is 2,558 feet for the Bucks Creek plant in the Feather River drainage area. Other plants exceeding 2,000 feet head are the Big Creek No. 1 and No. 2A in the San Joaquin River drainage and the Balch plant on the North Fork of Kings River.

The Big Creek No. 3 plant, having a capacity of 88,000 kilowatts, was the largest in California until the power plant at Shasta Dam was constructed.

The Shasta power plant has a rated capacity of 375,000 kilowatts. The ultimate installed capacity at Hoover Dam is 1,323,500 kilowatts.

The voltage at which hydroelectric power has been transmitted has increased and has enabled such power to be transmitted economically for increasing distances. Voltages of 150,000 were used in 1913, followed by 220-000 volts in 1923. Even higher voltages are now proposed.

Nearly all California power systems include both hydroelectric and fuel-electric plants. The ratio between the hydro and the steam plants' capacities has varied as their relative costs have changed. Hydroelectric power plants, with their transmission lines to load centers, usually have a larger capital investment per kilowatt of capacity and a lower operation cost per kilowatt hour of output than the similar costs for steam-power plants. The improvements in the fuel economy which have been made in recent years in the larger steam plants have tended to offset the effect of the upward trend in the price of the fuels used in steam generation. For the long-time view, the public interest will be best served by the use of the hydroelectric power resources, as such use utilizes a renewing source of energy while steam power consumes an accumulated source of fuel of limited total extent.

Prior to 1945 the steam capacity in the larger California power systems varied generally from one-third to nearly one-half of the total system capacity. In this period, steam power was generally used to carry system peaks, with hydro power carrying base load. In 1927 only 9 percent of the total kilowatt hours produced was generated in fuel-electric plants; this year had a better-than-average stream flow. From 1911 to 1927 an average of 20 percent of the total power generated in California was produced by steam plants. The hydro-steam ratio of installed capacity continued to be about 2 to 1 until World War II. After this war, increased construction of steam plants reduced this ratio to less than 1 to 1. By 1956 the hydro-steam ratio was 1 to 1.4 in northern California and 1 to 2.0 in southern California, In 1958 the hydro-steam ratio of the Pacific Gas and Electric Company was 1 to 1.7. Fuel power constructed in California in recent years has had greater capacity than the hydroelectric power.

In recent years, with the increased proportion of the new plants which produce fuel-generated power, both the proportion of hydro and steam capacity and the basis of their operation have changed. Hydroelectric plants are being operated to meet peak loads, with the base load carried by the steam plants. In 1958 the hydroelectric plants supplied 52 percent of the system generation of the Pacific Gas and Electric Company and 28 percent of the Southern California Edison Company. The larger rates of flow used by the hydroelectric plants at the peak hours can be met by draft on forebay storage above the plant. The resulting fluctuations in stream flow below the power plant can be reregulated to a uniform daily flow by the use of downstream afterbay storage.

Price of Power

There is no single basis on which the price or cost of power can be compared. The cost of power varies widely, depending on the method and the location of its production and its amount. At load center, power from alternate sources may become competitive. There is the usual large spread between wholesale and retail prices. The cost of local distribution and retailing results in the price per kilowatt hour for small consumers being much higher than the cost at the point of power production. These differences can be illustrated by examples.

Sales of the hydroelectric output between power companies and purchasers of by-product power produced at irrigation reservoirs prior to 1940 were

generally at prices varying from 3 to 4.5 mills per kilowatt hour for sales at or near the point of generation. The differences in these prices usually resulted from the amount and dependability of the power sold.

An essential item in the value of power is its dependability to meet the market it supplies. Hydroelectric plants may be subject to water shortages at times of peak demand. In recent years prices for wholesale purchases of power have been based on a price per kilowatt of dependable capacity plus a price per kilowatt hour for the power delivered within the power demand. Additional output, which may be available at times, may replace the use of fuel in steam plants and has a value based on the cost of the fuel it may replace.

In 1942 the State Engineer estimated that the cost of steam-power generation in northern California, based on a 6 percent return on the construction costs, was $12 per year per kilowatt of dependable capacity plus 1.8 mills per kilowatt hour produced. For plants operated at a load factor of 60 percent, these costs are equivalent to 4.1 mills per kilowatt hour.

Estimate of the Department of Water Resources of the sale value of the power output from state projects used in 1957 in Bulletin 3 were based on $22 per kilowatt of dependable capacity plus 2.8 mills per kilowatt hour produced.

For an average load factor of 60 percent this price for the output within the dependable capacity would have an average total value of 7.0 mills per kilowatt hour. When used for meeting peak demands with a load factor as low as 15 percent, the dependable output would be reduced in total amount but would have a value of two cents per kilowatt hour under the above capacity and energy components.

Total Hydroelectric Power Resources

In 1927 Bonner estimated the ultimate water-power resources of California as 7,390,000 kilowatts of installed capacity capable of producing 4,540,000 kilowatts of average output equivalent to about 40 billion kilowatt hours per year. In 1927 only about one-fifth of this potential power had been developed. The largest amount of potential power on any stream of the state was found to be on the Feather River.

These estimates did not include hydro power that may be generated on the Colorado River and brought into southern California. This was estimated to exceed 1,000,000 kilowatts.

Studies in 1944 by federal agencies resulted in the conclusion that in northern and central California there were about 1,860,000 kilowatts of undeveloped hydro power in single-purpose projects and about 900,000 kilowatts of similar power in multiple-purpose projects. These results represent nearly the entire unused hydroelectric power resources of the state, as the remaining power resources within southern California are limited. The sum of the power then developed and these estimates is about 5,750,000 kilowatts.

In 1953 the Federal Power Commission again estimated the potential water-power resources. For the entire United States a potential capacity of 109,500,000 kilowatts producing 491 billion kilowatt hours per year was found. Of this total 10,625,000 kilowatts were found in California, of which 2,822,000 kilowatts were developed in 1953. This represents a then development of 27 percent of the potential supply.

The increase in the estimates of total potential hydroelectric power from 1927 to 1953 is the result of more complete information regarding the available power sites and plans for installations of larger installed capacities to operate on lower load factors to meet peak loads.

There is only so much fall and so much water supply on California streams.

These set a physical limit on the amount of hydroelectric power which can be developed. Economic conditions will limit the amount of the physically available power which will be developed. At the rapid rate at which new plants are being planned and constructed, California can look ahead to a time, not too far in the future, when the available hydroelectric projects which can produce power on a competitive basis with other sources will be fully used. Economic conditions change and neither the amount nor the time when such full development may be reached can be specified.

Power Development on Public Lands

The lands in the areas where hydroelectric power may be developed belong very largely to the federal government. Plants requiring rights of way on such public lands must meet the terms of federal statutes as public lands are not subject to condemnation.

Of the hydro plants in California in 1927, only 16 percent of the capacity was in plants located entirely on private lands. The remainder utilized rights of way over public lands under different types of permits and licenses from the federal government. Of the remaining hydroelectric resources of the state, it was estimated that over 90 percent would require the use of public lands.

In common with other policies relating to public lands, the statutory procedures for acquiring rights of way for power use have varied as public thinking in this field has progressed. As discussed in chapter III, there were no means by which early settlers could secure title to public lands, so that possessory titles came to be recognized under local customs. These were also recognized by the federal government under the Act of 1866. The Act of 1891 provided for rights of way over public lands for irrigation on proper application to the federal land office. In 1898 this act was enlarged to include power where it was subsidiary to irrigation. The Act of 1901 established a system of revocable licenses for rights of way over public lands with the jurisdiction over unreserved lands placed with the Department of the Interior and for lands in forest reserves with the Department of Agriculture. Such permits were for periods of fifty years unless revoked by the controlling secretary. Annual fees based on the power obtainable were charged, although their amounts were relatively small.

These acts were replaced in 1920 by the Federal Power Act creating the Federal Power Commission. This Commission has jurisdiction over all uses of public lands for power purposes except in the National Parks. Licenses are issued for fifty-year periods and are revocable only for cause. Annual fees are charged to cover rental values of the lands used and administrative costs. The Federal Power Commission may regulate the rates charged for power produced by plants using rights of way over public lands if the state in which the project is located does not regulate such rates.

Section 7 of the Federal Power Act contains the following provision:

"(a) In issuing preliminary permits hereunder or licenses where no preliminary permit has been issued and in issuing licenses to new licensees under Section 15 hereof the Commission shall give preference to applications therefor by states and municipalities, provided the plans for the same are deemed by the Commission equally well adapted ... to conserve and utilize in the public interest the water resources of the region;"

The Commission is also directed to give preference "to the applicant the plans of which it finds and determines are best adapted to develop, conserve, and utilize in the public interest the water resources of the region, if it be satisfied as to the ability of the applicant to carry out such plans."

These two provisions may conflict if the public agency applying for a license does not propose a project making the fullest use of the available power resources. To date, these two directives to the Commission have not resulted in any serious conflicts in California projects.

Water and Power Act

One of the controversial episodes in the history of hydroelectric power in California was the so-called Water and Power Act. This was an initiative measure on the state ballot in the general elections of 1922 and 1924. It was defeated by large majorities in both elections.

This act would have created a Water and Power Board, authorized to borrow up to $500,000,000 on the credit of the state to be used to buy or to build power projects to be operated by the Board. The Board would have had the right to reserve from other uses the waters it might need, could buy power generated by others, could build distribution systems for political subdivisions, and could sell power to any users with preferences in such sales to the state or its political subdivisions. Not over 20 percent of the Board's total output could be sold to private utilities. Rates charged for power were to meet the costs and bond charges, with the state obligated to pay any deficits.

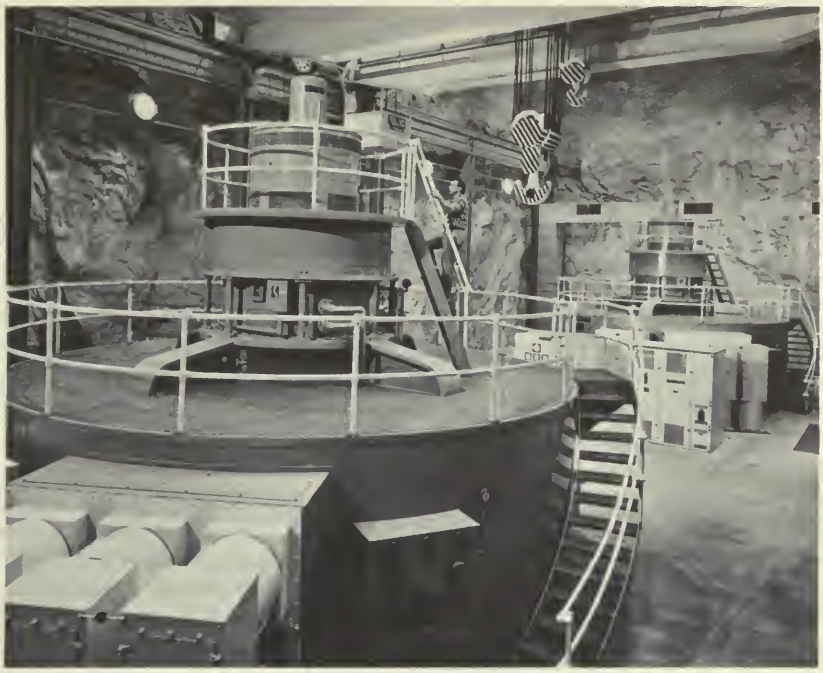
This proposed act was the first organized move to secure general public ownership of power in California. The issue was widely and heatedly discussed. While many different motives may have governed the way in which individuals voted on this measure, the dominant causes in its defeats were probably unwillingness to have the state embark on development carrying a state liability for the costs and the public distrust of the sponsorship of this particular act.

Power Development by Public Utilities

Early distribution of electric power in California was generally by private companies which operated as public utilities. These are still the principal power agencies in the state. Early development was by a number of separate local systems, with some overlaps in the areas they served. Gradually these smaller systems were combined for better economy, until now nearly all public utility power service is supplied by the Pacific Gas and Electric Company in northern California and by the Southern California Edison Company in southern California.

The Pacific Gas and Electric Company was organized in 1905 by a merger of two then existing companies. Other companies have been acquired at various times. The largest acquisitions were the Great Western Power Company and the San Joaquin Light and Power Corporation in 1930.

In 1958 the Pacific Gas and Electric Company's system included 62 hydro and 14 steam plants with a total installed capacity of 5,219,000 kilowatts and 71,100 miles of transmission lines. The capacity of the hydro plants was 1,922,500 kilowatts and that of the steam plants was 3,296,500 kilowatts. This company supplied service to 1,850,000 electric customers in 47 California counties having an estimated population of 6,310,000. The electric sales were 18,486 million kilowatt hours. This was used 25 percent by residential or domestic customers, 11 percent by small light and power users, 42 percent by large light and power users, 14 percent in agriculture, and 8 percent by miscellaneous purposes. The average price received was 1.84 cents per kilowatt hour. The average rate per kilowatt hour for residential use was 2.7 cents, for small power use 3.2 cents, for large power users 1.3 cents, and for agriculture 1.5 cents. Of the total power generated in 1958, 52 percent was produced by hydro plants; this percentage for 1958 was larger than usual as a result of the above-average water supply of that year.



Pacific Gas and Electric Company photograph

Haas Powerhouse. Interior View, showing Underground Construction in Rock Excavation

Pacific Gas and Electric Company photograph

Wishon Dam and Reservoir on North Fork of Kings River

The hydroelectric power resources of southern California are limited. While there are fairly high mountains, the higher elevations have too small an area to produce sufficient runoff for large power production. The available local power sites were developed where feasible but were soon insufficient to meet the demand. Power was developed on the San Joaquin River and on streams in the Tulare Lake Basin and transmitted to the southern California coastal area. Several of the early public utility companies have been combined in the Southern California Edison Company.

In 1958 the Southern California Edison Company had a total generating capacity of 3,404,000 kilowatts and generated 15,825 million kilowatt hours, of which 28.5 percent was produced by their hydroelectric plants. This 1958 hydro output was about 50 percent larger than in 1957 as a result of the more favorable stream flow. This company also receives power from Hoover Dam; in 1958 this amounted to about 6 percent of their total supply. Only about 20 percent of their installed capacity is in the company's hydro plants. This is a reduction from 30 percent in 1949.

Publicly Owned Power

Public ownership of power has been a recognized activity of public agencies, such as municipalities and irrigation districts, wherever the voters of the areas in such agencies desired to engage in power generation or distribution. The largest municipal system in the state is that of Los Angeles; this is the third largest producer and distributor of power in California. In the year 1957-58 Los Angeles had 1,683,000 kilowatts of generating capacity. This capacity produced 5,889 million kilowatt hours and 1,571 million kilowatt hours were received from Hoover Dam.

San Francisco produces power along the Hetch-Hetchy Aqueduct at the Mocassin Creek power plant with a capacity of 72,400 kilowatts. This power was transmitted to San Francisco and distributed by the Pacific Gas and Electric Company until court decisions ruled this sale was a violation of the Raker Act under which San Francisco secured its rights of way in Yosemite National Park. The output of this plant is now sold to the Modesto and Turlock irrigation districts. At several different elections San Francisco has defeated proposals to acquire and operate power distribution systems within its own area.

There are about twenty municipalities in California which have publicly owned power distribution systems serving within their areas. Only five of these generate all or part of the power which they distribute; the others purchase power at wholesale for distribution by the municipal systems. Among the cities distributing power are Alameda, Burbank, Glendale, Palo Alto, Pasadena, Redding, and Riverside. The East Bay Municipal Utility District has a 15,000-kilowatt plant at Pardee Dam and sells the power produced to the Pacific Gas and Electric Company. Glendale and Pasadena operate steam plants to supply part of their power demands. The Sacramento Municipal Utility District acquired the local distribution system serving Sacramento and the adjacent areas and distributes power purchased mainly from the U.S. Bureau of Reclamation. The district has its own power projects under construction on the American River.

California irrigation districts which generate and distribute power within their areas include the Modesto, Turlock, and Imperial districts. Other districts generating power and selling it to public utilities include the Oakdale, South San Joaquin, and Merced districts. The Nevada Irrigation District sells the use of its stored water as it passes through power plants of the Pacific Gas and Electric Company enroute to irrigation within the district.

In 1923 about 6 percent of the total power production in California was generated in publicly owned plants; in 1927 this had increased to 14 percent, and in 1945 to 25 percent. These results do not include power produced in federally owned plants. Of the power generated by publicly owned systems in 1945, about 70 percent was produced by Los Angeles.

Federally Owned Power

In addition to privately owned public utilities and publicly owned power systems, a third type of power ownership has entered the California field. This is the federally owned and operated projects. Privately owned public utilities are regulated by the state both as to their rates and as to their service. Public power systems owned by their local consumers are under their own local control. In each of these types of ownership, the users of power have direct access to forms of regulation controlling their service. The federally owned power projects are subject only to such limitations as Congress may impose in the authorizing statutes and individual consumers do not have access to regulatory agencies having authority over the federal bureaus building and operating such federal projects. Such federally controlled power systems are a relatively recent development in California. Expansion in federal activity in the construction of water-utilization projects, with the development of the by-product power which such projects make available, has made the federal power agencies an important factor in this field.

The act of April 16, 1906, authorized the Secretary of the Interior to lease any surplus power or power privilege on any project under the Reclamation Act for periods of not to exceed ten years. Receipts from such leases were to be covered into the Reclamation Fund to the credit of the project from which such power was derived. In such leases preference was to be given to municipal purposes. No such power leases were to impair the efficiency of the irrigation project. The first Bureau of Reclamation power plant placed in operation was on the Minidoka Project in 1909.

The Bureau of Reclamation found power a more dependable source of income than collections for the repayment of the construction costs of irrigation systems. Beginning about 1925 the policy expressed in the 1906 act was changed and the power facilities retained for operation by the government. Previous contracts turning over power plants to the contracting irrigation organizations could not be changed. On present projects the cost allocated to the power features is not charged to the land but is carried by the government to be repaid from the sale of power. In the earlier projects the power produced in excess of project needs was sold to local public or private agencies without transmission to the purchaser by the Bureau. It is only in recent years that Congress has authorized the construction of transmission lines for other than project use.

The Reclamation Project Act of 1939 amplified the preference in sale of power to "municipalities and other public corporations or agencies and also to cooperatives and other nonprofit organizations financed in whole or in part by loans made pursuant to the Rural Electrification Act of 1936 and any amendments thereof." Sales or leases of power were not to be made for periods exceeding forty years. The rates for power were to be "at least sufficient to cover an appropriate share of the annual operation and maintenance cost, interest on an appropriate share of the construction investment at not less than three percentum per annum, and such other fixed charges as the Secretary deems proper." No contract relating to power was to be made that would impair the efficiency of the project for irrigation purposes.

The provisions in the Reclamation law relating to preference to public

agencies in the sale of power developed on reclamation projects have been the basis of extensive controversy in the Central Valley Project. The Bureau of Reclamation contended this provision represented authority to distribute power from project power plants to public agencies desiring to purchase it. The existing utility in the project area contended such preference was limited to public agencies in a position to take the power where it was produced. The provisions of the Reclamation Act of 1939 relating to allocation of costs to power and power rates have also been the subject of wide differences of opinion.

Nationally, the installed capacity of federal hydroelectric power plants on January 1, 1953, was about 8,290,000 kilowatts, with 6,340,000 kilowatts additional under construction. A little over half of this total was represented by plants of the U.S. Bureau of Reclamation, with the Tennessee Valley Authority and the Corps of Engineers, U.S. Army, the other large federal power agencies. In 1953 in California there were 577,600 kilowatts of installed federal hydro power.

The first federally constructed power plant in California was that at Siphon Drop on the Yuma project. The output of this plant is used on the Yuma project; its financial returns are credited to the repayment of the costs of the Yuma project which is mainly in Arizona.

The Boulder Canyon Project, while not in California, is mainly a power project with the power produced used principally in California. Congress required firm contracts for the sale of its power output at prices which would repay its costs before its construction was undertaken. These contracts were secured at rates which have and will meet all repayment terms for this project. The power output is delivered to the contractors at Hoover Dam.

Power is also generated at Parker and Davis dams on the Colorado River. Part of the power from Parker Dam has been used in Arizona. The Bureau of Reclamation has not undertaken to distribute power in California from its Colorado River power plants.

In the Central Valley Project, power is generated at the Shasta and Keswick dams on the Sacramento River and at the Folsom and Nimbus dams on the American River. Part of this power is required for project operations in pumping water from the Sacramento drainage into the San Joaquin Valley. The power produced exceeds the power needed by the project and the project plans were based on selling the surplus power at rates which would meet a large part of the reimbursable costs of the project. Much controversy arose over the conditions and terms of such sales of surplus power. These controversies have not been fully settled as yet. To date, the power output in excess of that taken by public preference customers has been sold to the Pacific Gas and Electric Company. The disposal of the power which will be made available from the Trinity project has also been an active political question. These matters are discussed more fully in chapter XII.

Hydroelectric Power and Irrigation

Hydroelectric power has interferred with the water supply for irrigation in only a few instances in California. On many streams power has been a material aid to irrigation. As the regulation of the Sierra streams for power brings their flow more nearly within the irrigation demands than the unregulated natural flow, storage for power above the points of irrigation diversion increases the low-water flow available for irrigation. As the power development is practically all within the mountains or in the edge of the main valleys above the points of diversion for irrigation, power use does not deprive irrigation of the available water. In several irrigation reservoirs, the power

developed has been a major factor in reducing the cost to irrigation. Use for power does not consume the water used; any effect on irrigation, for power plants above the points of irrigation diversion, is limited to changes in the time of the occurrence of runoff.

Where power development is made on a stream below areas adapted to irrigation, conflicts over the water supply will arise if the total supply available is insufficient for both uses. Irrigation is a water-consuming use and depletes the stream flow. Upper irrigation reduces the flow available for lower power use. The upper Pit River valleys represent areas where irrigation use reduces the flow that would otherwise be available for use for power by plants in the lower portions of the river. All Pit River power plants are above the Sacramento Valley and any water of this stream used for power remains available for use in the lower valley.

Rights to the use of water for generation of power are acquired on the same basis as for other uses of water. The power rights acquired are valid as long as they are used. The 1911 Water Conservation Commission Act provided for twenty-five-year licenses for water rights for power with an annual fee for the use of water. This annual fee was removed in the 1914 Water Commission Act. Appropriation rights acquired after 1914 are subject to a right to purchase after the expiration of twenty years by the state or other public agency.

Desirable power sites may result from the construction of storage for irrigation. The depth of the storage provides the power head and the draft for irrigation provides the flow. When the dam has been built, the additional costs of power outlets and generating facilities are relatively low. Several power plants have been built to develop such power. Examples of these are the plants at the Don Pedro Dam on Tuolumne River, the Exchequer Dam on Merced River, the Melones Dam on Stanislaus River, and Shasta Dam on the Sacramento River.

The power produced at an irrigation reservoir has varying characteristics. If the full flow of the stream is used for irrigation, the power output will be seasonal and limited to the months of draft for irrigation use. If the irrigation project does not require the full annual flow for its needs, the surplus water can be used to generate winter power. If the irrigation use requires drawing the full amount of water stored, the depth of storage will be small toward the end of the irrigation season and the power output reduced even if the rate of flow is maintained. Such power is not well adapted for general power loads but may fit the power demands for irrigation pumping.

Competitive Position of Hydroelectric and Steam Power

The report to the Federal Power Commission on the Water Powers of California by Frank E. Bonner, published in 1928, contained the following comments, after noting that the trend at that time was toward producing a larger part of the total output by steam than had been the earlier practice.

"This trend toward larger use of fuel-generated power is further influenced by the recent improvement of steam plant design and the present low price of oil. According to most forecasts the latter is a temporary situation, but the higher steam plant efficiencies now practicable, as illustrated by the production of 450 kilowatt hours per barrel of oil at modern plants, have narrowed the margin of economic advantage hitherto possessed by hydro. Increasing difficulties over water rights, unfavorable legislation, and recent adverse decisions in the California courts have served to increase water-power development costs, and still further to impair the advantage of this source of power."

These comments correctly represented this situation at the time they were made. The decision of the State Supreme Court in the Herminghaus case had left power development involving storage subject to the claims of lower riparian owners. Costs of fuel oil at that time were relatively low.

Since 1928 the constitutional amendment of that year has reduced the grounds which lower riparian owners could use to exact tribute from upper development; the cost of oil has increased and is generally expected to increase further with the decrease in the locally available oil resources; and the efficiency of steam plants has increased so that outputs of over 600 kilowatt hours per barrel of oil are obtainable in modern plants. While this last factor favors steam power, it is not sufficient to offset the probable increases in the cost of fuel for steam generation. Interest in hydro-development has increased and projects formerly considered to be too costly to compete with steam are becoming feasible.

Public Versus Private Power Development

There are several forms of public agencies under which power consumers can organize for the development and operation of their own power service. Municipalities may develop and distribute power and various forms of utility acts may be used. The right of power consumers to provide their own power service is fully established.

The right to provide publicly owned power service does not establish its desirability nor its economy. Whether such public power development may be desirable in any individual area depends on the local conditions and the preference of the voters in the area.

Power service is not one of the required functions of government. All governments are responsible for providing for the health, safety, and education of their people. These are basic and required services if any government is to function. In addition, there are optional functions which a government may perform where they serve the interests of those governed or where those governed desire such services to be supplied by their governing agency. These optional functions are services which can also be provided by private agencies. It is to be expected that some governmental agencies will provide such services and that others will have them performed by other agencies. Power is one of these optional services. As such optional services require ownership of systems not needed for the basic functions of government, they have been called "proprietory functions" of the governing agencies.

For basic governmental functions, the governing agency is tax exempt on its property used in such services, has special rights (such as the power of condemnation), and can use its taxing resources as the security for its financing. For proprietory functions, public agencies have been given the same powers. This results in placing public agencies supplying power service to their members at a material economic advantage over competitive privately owned service. It is this advantage which has caused the extensive arguments regarding the relative merits of publicly or privately owned power service.

The principal competition in power service is between the public-owned agencies and the privately owned systems operating as public utilities. Public utilities in California have the power of condemnation, so that the principal differences between these two forms of power service relate to the tax exemptions and rights to tax of the two forms of organization. There has also been much discussion regarding the relative efficiency of operation of public and private agencies. Both secure their staffs from the same general population and have similar opportunities to secure capable personnel. Which form of agency may attract the more capable staff and which may furnish the

better incentives for sustained efficiency is necessarily a matter of opinion not subject to a conclusive answer.

With the rapid increase in rates of taxation in recent years, there has been a material advantage for public tax-free agencies. Privately owned public power utilities are now subject to forms of taxation amounting to over 20 percent of their total income. A publicly owned power system not subject to taxation has an opportunity to supply service with this economic advantage. Those receiving interest payments or dividends from privately owned utilities are subject to tax on such income. Interest on bonds of publicly owned utilities is tax exempt. For present rates of income tax, this difference is a material factor for investors in the higher income brackets and results in lower costs of financing for the publicly owned projects. The power to tax general property in the public districts is an added element in their securing lower interest rates where general obligation bonds are used.

The exemption from taxation of the publicly owned power districts is sometimes referred to as a saving in taxes. While such an exemption is a tax avoidance for the public agency, it is not an actual over-all tax saving. Tax savings can only result from a reduction in the spending of funds secured by taxation. As long as the same tax expenditures are maintained, any exemption to one class of property or business merely increases the tax required to be secured from those not within the exemption.

Whether a public agency engaged in proprietory types of business should be given a preferential cost position at the expense of areas served by privately owned utilities has been the subject of much discussion. The actual conditions and results have been obscured in much of this discussion by the disputes regarding general forms of government represented by such public ownership. Any group of power users should be entitled to be served by the agency of their choice. However, this does not mean that public forms of service agencies should be subsidized at the expense of those preferring to be served by privately owned agencies.

Many attempts have been made to compare the costs of power under public and private ownership. With so many differences in the conditions under which separate systems may operate, such comparisons usually require interpretations of the records on which different individuals may reach different conclusions. To date, the larger privately owned public utilities appear to have used the economies resulting from the greater diversity of the loads which they serve to offset the tax exemption advantages of the public agencies serving only local markets.

CHAPTER IX

Reclamation

Usage of the term "reclamation" in California has differed from that of other western states. In California, reclamation is generally used for the reclaiming of land from overflow; in other arid states it is usually applied to the reclaiming of land by irrigation. In California, reclamation districts are primarily levee districts to keep surplus water off land so that it can be farmed; actually, most of the land so reclaimed requires irrigation to enable it to produce crops. The other usage of the term is illustrated by the title of the federal bureau engaged in providing irrigation water to arid lands; this is called the Bureau of Reclamation.

There is no contradiction in having lands which require both reclamation from overflow and irrigation. Surplus runoff occurs during the period of melting snow and from floods following severe winter storms. At other times in the year, the rainfall may be inadequate to meet the needs of the crops on the overflow lands.

Overflow occurs where there are areas of low-lying lands adjacent to streams subject to large rates of flow. Large areas of such lands occur in the troughs of the principal valleys in California where the slopes are insuf-

ficient to enable the streams to maintain deep channels and where the deposit of alluvial material may result in raising the stream above the adjacent trough areas. Overflow lands are much more extensive in the Central Valley than in southern California.

Reclamation of overflow lands began relatively early in the development of the state. Such works were built by the owners of the protected lands. Later, state aid was extended on the major projects. Finally, the federal government adopted flood control as a federal responsibility and has now become the major factor in this field. Present reclamation is being accomplished mainly as a part of flood-control projects rather than as separate local reclamation works. Reclamation of overflow lands after 1936, when the federal government undertook flood control on an enlarged scale, is discussed later in chapter X.

Federal Legislation on Swamp and Overflow Lands

Congress passed a Swamp Land Act in 1849, applicable to Louisiana, and extended it to other states in 1850. This act is frequently referred to as the Arkansas Act, as it was largely intended for use there; the lands acquired under its terms are known as swamp and overflow lands. This act granted areas conforming to the classification of swamp and overflow lands within their borders to those states accepting its provisions. This grant was made in order that the states might supervise the reclamation of these lands. Only states having such lands and admitted to the Union at the time of the passage of the act were included within its provisions. California came within the provisions of the 1850 act, as its admission on September 9, 1950, was just ahead of the effective date of the Arkansas Act, September 28, 1850. The act of March 12, 1860, gave the states the right to designate the areas within their boundaries which were swamp lands.

Extent of Swamp and Overflow Lands

In his report to the Legislature in 1880 the State Engineer classified 1,100,000 acres of swamp and overflow lands in the Sacramento Valley with an additional 600,000 acres in the San Joaquin Valley and the Delta. By 1880, 550,000 acres of the area in the Sacramento Valley had been listed to the state. By 1904, about 2,000,000 acres had been listed to California by the United States and patents for this area had been issued by the state. By 1922 the area of swamp and overflow lands patented in California was a little over 2,000,000 acres, out of the total patented in the United States of 64,000,000 acres. Little further public lands eligible to acquirement under the Swamp and Overflow Act remained in 1922 and the use of this act had nearly ceased.

Early State Legislation on Swamp and Overflow Lands

The terms and conditions for acquirement of swamp and overflow lands set by the state have varied at different times. The 1855 act set a purchase price of one dollar per acre and limited each purchaser to 320 acres. At least one-half of the area purchased had to be reclaimed during the purchase period. Few sales were made under this act. In 1858 the terms were amended so that the dollar per acre purchase price was to be placed in a swamp-land fund and the requirement for reclamation was removed. In 1859 the area an individual could purchase was increased to 640 acres, with 20 percent of the purchase price to be paid at the time of purchase and the remainder within five years thereafter.

An act in 1861 provided for the organization of reclamation districts. On petition of one-third of the lands in an area, the state board could plan its reclamation works and expend one dollar per acre from state funds on their construction. If, as was the actual case, the necessary costs for reclamation exceeded one dollar per acre, there were no sources from which the additional funds needed could be secured except the voluntary contributions of the landowners. The board recommended in its first annual report that a law be passed providing for the taxation of the reclaimed land for the remaining costs in excess of that secured from the state fund. This appears to be the earliest proposal in this state for the use of the taxing power for land reclamation or irrigation.

In 1862 the Legislature authorized the levying of an assessment upon petition of the owners of one-third of the land in the district. This procedure was not successful, and the board again recommended authority to levy taxes without petition; this authority was not given. By the end of 1862 thirty-eight swamp-land districts, having a total area of 485,000 acres, had been formed and $79,000 of the legislative fund of $200,000 had been expended. By 1865 seven more districts had been formed. In 1866 the Board of Swamp Land Commissioners was abolished and its funds and duties transferred to the counties. The county engineer was made the engineer of the districts in his county. This resulted in each county following its own policy with no consistent general progress.

In 1868 additional provisions covering formation of districts and their functioning were passed. The maximum limit on the area that could be acquired was removed. General procedure and practice by county supervisors were somewhat lax but development was rapid. Within a three-year period most of the swamp lands in the state were patented. This act required a showing that reclamation had been completed and crops grown successfully for three years.

In 1872 the requirement of three years of successful cultivation was removed. Patents were to be given either on a showing that the reclamation works had been completed or that two dollars per acre had been spent on their construction. In 1874 the maximum limit on the area one person could buy of 640 acres was restored.

The need for supervision and control of reclamation by the state was recognized by William Ham Hall, the State Engineer, in 1880. He recommended that the state should exercise such control over reclamations

"...as will regulate their use, promote their improvement, and systematize the construction and management of all works designed to promote rapid drainage and prevent inundations."

These principles were adopted for the Sacramento and San Joaquin Drainage District when it was created by the state in 1911.

In 1893 the Legislature established a procedure for acquiring state lands which had been uncovered by the recession or drainage of the waters of inland lakes. Applications were to be made to the State Surveyor-General similar to those for general swamp and overflow lands. Applicants were limited to persons owning less than 640 acres of state land, including the area covered by the application. If the uncovered lands were subject to cultivation without reclamation, individual purchases were limited to 320 acres. The price of such lands was to be $2.50 per acre and the terms of payment the same as for swamp and overflow lands. Under this act, applications were made to purchase about 200,000 acres in 1902-1904, the largest area being in Tulare Lake.

Lands within reclamation districts lying below the flood plane and having

only partial protection from the larger floods were not suited to subdivision into small farms and residences. This condition has been recognized in the reclamation district act and voting has been based on land ownership without requiring residence within the district. Each owner is entitled to one vote for each $100 of his assessed value. The costs of district works are assessed in accordance with the benefits each ownership or area receives.

Large Holdings of Swamp and Overflow Lands

In 1872 J. Ross Browne reported that the Anglo-American Syndicate of London had bought 250,000 acres of swamp and overflow land. Of this, 50,000 acres were in salt marshes around San Francisco Bay and the remainder about equally divided between the Sacramento and the San Joaquin valleys. The Tide Land Reclamation Company owned about 120,000 acres of swamp land in the Delta; Twitchell Island had been reclaimed and reclamation on Grand Island was well along. The Sacramento Valley Reclamation Company was reported to have nearly completed the reclamation of 120,000 acres on the west bank of the Sacramento River extending down stream from Knight's Landing.

The acquirement of swamp and overflow lands in large holdings was an early source of concern. In 1872 a Special Committee on Land Monopoly of the State Legislature found several single individuals had purchased areas in excess of 30,000 acres, the largest found being 81,580 acres.

A report was also made by the joint committees on Swamp and Overflow Lands and on Land Monopoly to the twentieth Legislature in 1874. These committees concluded that there had been connivance in segregating nonswamp land as swamp and overflow land and that such connivance included the federal land department. This had resulted from the loose land laws and their lax administration. The committee report contained over three hundred pages of testimony covering cases of swamp and overflow land and locations of land script.

Procedure relating to the acquirement of swamp and overflow lands was handled with similar laxity to that usual for all public lands during the early history of the state. Strictness in enforcing full requirements of the land laws was generally lacking in the period when there was a large surplus of land and a scarcity of population. Land had little value under such conditions and little check was exercised on its acquirement.

Among the requirements for the segregation of swamp and overflow lands was a declaration of the character of the lands and their liability to overflow. A convincing proof of overflow was to certify that the applicant had been over the land in a boat. Local rumor in some of such cases was to the effect that the applicant had actually been over the land in a boat, but, that while the applicant was seated in the boat, the boat was seated in a wagon being drawn over dry land. These rumors were sufficiently strong to result in some individuals being given the local title of commodore or admiral on the basis of such naval service.

Status of Reclamation Districts to 1931

In a report on the reclamation districts in California, published as Bulletin 37 of the State Division of Water Resources in 1931, the record is divided into three periods. From 1861 to 1866 forty-five districts were organized and became active under generally careful administration. Two of these districts were still active and approximately all of the areas included in the others are now included within other present districts. From 1867 to 1911 such districts were directed by the county supervisors and there was little coordination in

the practices in the different counties. Seven hundred seventy-two districts were organized, of which eighty-six were active in 1931. The reclamation works accepted as qualifying for the allowance of completed reclamation from the swamp-land fund were inadequate in many cases.

In 1911, after the creation of the Sacramento and San Joaquin Drainage District and its administration by a state-appointed board, reclamation standards improved. While the State Reclamation Board did not have control over the organization of reclamation districts in the area of the Sacramento River and its tributaries, its approval was required for the construction of any reclamation works within the area of this district. In the period from 1911 to 1930, 119 reclamation districts were organized, of which ninety-four were active in 1931. Of the total organized, seventy-six were within the area of the Sacramento and the San Joaquin rivers. Reclamation in the area formerly covered by Tulare Lake was also active in this period; there were twenty-six reclamation districts in this area in 1931. From the beginning to 1931, a total of 931 reclamation districts were organized. Of these, 182 were active at the end of this period.

While the statutes permitted the issuance of bonds by reclamation districts, this was not done prior to 1911. Over $15,000,000 had been spent on such reclamation by 1903 and many areas of high land value had been created. Construction costs were financed by direct assessment or borrowing from sources of private capital. The lands were generally handled in large holdings and colonization was not generally undertaken.

The districts formed from 1911 to 1930 were usually ones requiring more extensive works and having higher costs. Many of these districts voted and sold bonds. To January 2, 1931, sixty districts had voted bonds. In three districts these had been paid in full; seven had cancelled their original bonds after their reorganization; three had voted refunding bonds; eighteen districts having nearly $7,000,000 of outstanding bonds were in default; and thirty-two districts had nearly $25,000,000 of outstanding bonds without defaults.

Various causes were responsible for these defaults. These included the change in agricultural conditions resulting from the "anti-alien" land law, too heavy indebtedness, too short amortization schedules, failures of water supply, and engineering or management defects. During the depression of the 1930's defaults increased. The reclamation districts were included in the refinancing provisions of federal laws for drainage and irrigation districts and received similar treatment from the Reconstruction Finance Corporation in the adjustment of their bonded indebtedness.

Present Status of Reclamation

The reclamation of areas in the Delta began in 1849, with the construction of a levee on Grand Island. Early levees were generally inadequate in height and strength and failures were frequent in years of large floods. As the channels were raised by the deposit of mining debris, it was necessary to increase the height of the levees. Methods of construction have included Chinese labor using wheelbarrows, peat side walls with sand cores placed by suction dredges and more recently long-boom dredges. The irrigable area in the Sacramento-San Joaquin Delta is about 400,000 acres.

The Delta consists of separate areas or islands surrounded by the channels or sloughs of the river. Overflow of these channels results in deposits of sediment along their banks raising the margins of the islands above their interior area. The lower areas prior to reclamation supported a dense growth of tules which formed peat soils. It is this organic soil which distinguishes the Delta from the overflow lands along the channels of its tributary streams.

While these peat soils are very productive in the crops for which they are adapted, their gradual subsidence under continuing cultivation results in increasing difficulties in their drainage. Water is admitted to the island areas when needed for irrigation and removed when an excess occurs.

Practically all of the suitable land in the Delta has been reclaimed. Present levees are generally adequate to protect their inclosed areas. The heights to which levees can be maintained are limited by their foundation conditions; too great height and weight result in settlement. While the levees have been built to protect the enclosed lands under the natural range of tides, any increase in the average height of water in the Delta, or an increase in the length of time water would be maintained at high-tide elevations, would result in maintenance problems which much of the Delta might be unable to meet. These are conditions which require recognition in plans for any form of bay barrier.

Reclamation of the overflow lands in the Sacramento Valley began in the 1860's. It progressed through the usual sequence of inadequate levees, increased levee heights, independent separate efforts, and, finally, to a recognition that the reclamation of the trough lands was a general, rather than a local, problem. The Sacramento and San Joaquin Drainage District was created by the Legislature in 1911. Since this date, all further reclamation works are required to conform to a general plan of reclamation. The present bypass system of flood control is designed to provide reclamation for the lands formerly subject to overflow. This project is discussed in the chapter on flood control.

Reclamation in the San Joaquin Valley also began early in the settlement of the state. The Legislature in 1857 granted the Tulare Canal Company the odd-numbered sections of swamp and overflow land belonging to the state between the San Joaquin River at Kings River Slough and Tulare Lake and similar lands bordering Tulare, Buena Vista, and Kern lakes on the condition that a canal capable of use by eighty-ton boats would be built from Kern Lake to Kings River Slough. Construction was to begin within one year and be completed within three years. After twenty years of operation the canal was to revert to the state. This act was repealed in 1858 and re-enacted in 1862. The total area granted was estimated as 211,000 acres. In 1863 the obligation to build the canal was repealed but the land grant was continued for the reclamation of these lands. Reclamation works were begun and a patent for 89,120 acres was signed by Governor Low in 1867. The Surveyor-General of the state had inspected these lands during a drought and reported that they were reclaimed. This patent was annulled by the courts in 1878. Some of the lands had been sold to settlers prior to this annulment and the 1878 Legislature gave title to those buyers who had spent not less than one dollar per acre for their reclamation.

The report of the State Engineer in 1880 gives the early history of the reclamation of the swamp extending northward from Buena Vista Lake toward Tulare Lake. The Kern Valley Water Company, for Swamp Land District No. 121, constructed a canal 125 feet wide on the bottom and 24 miles long on the west side of the swamp lands. The cost of this canal and other works was $324,000. This canal was intended to carry the flood waters of Kern River and the overflow of Buena Vista Lake around the swamp area to be reclaimed. Navigation to Tulare Lake was also planned. To secure water for navigation and irrigation, Buena Vista and Kern lakes were to be converted into reservoirs. Adverse claims to the swamp lands in these lakes prevented the completion of the project and left the swamp lands in District 121 without an adequate irrigation water supply after their reclamation from overflow. Diversions by upper canals left insufficient flow in Kern River for these lower

lands; this condition later supplied the basis for the famous Lux vs. Haggin suit previously discussed, which established the riparian doctrine in California.

State Reclamation Board

A State Reclamation Board of three members, to have jurisdiction over reclamation in the Sacramento Valley, was established by the Legislature in 1911. In 1913 this board was increased to seven members, appointed by the Governor, and its jurisdiction extended to the San Joaquin Valley. The 1913 act created the Sacramento and San Joaquin Drainage District containing nearly 1,750,000 acres within the flood plane of the Sacramento and the San Joaquin rivers. The flood-control project for the Sacramento River proposed by the California Debris Commission was adopted. The Reclamation Board has jurisdiction to control reclamation works of local districts so that they will not interfere with this plan. The Board also maintains the flood-control project, actual work in such maintenance is now performed by the Department of Water Resources. The part of the cost of the reclamation works of the general project to be paid by local areas is assessed on the basis of the benefits produced by a Board of Assessors appointed by the Reclamation Board. Such assessments, when they become final, are tax liens on the land assessed.

The State Reclamation Board has supervised reclamation in the area of the Sacramento–San Joaquin Drainage District since its creation. The by-pass system of flood control and reclamation for the Sacramento Valley has been largely completed except for the reclamation of Butte Basin. A revised plan for the San Joaquin River has been adopted recently and its construction begun.

CHAPTER X

Flood Control

The distinction in the California usage of the terms reclamation and irrigation has been discussed in the introduction to chapter IX. A similar distinction is needed for the difference between reclamation and flood control.

In general, the term reclamation has been used for those local projects built by reclamation districts for the benefit of their included lands. Similarly, the term flood control has been used for projects affecting larger areas or entire streams where some state or federal construction or financial aid is involved. Earlier efforts to protect lands from overflow were uncoordinated and often competitive. Present projects are usually designed for the benefit of the entire stream. In this chapter the projects and policies discussed are those designed for the benefit of all the lands on a stream which may be subject to flood damage. Flood control, as its name implies, usually attempts to control the flood by storage or by the use of artificial stream channels. Reclamation is usually limited to the effort to keep water off of low-lying lands without changing the amount or the time of the occurrence of the flood flows.

Flood control may be secured by storage, by levees to confine floods with-

in the stream channels, by by-passes to convey flows in excess of the channel capacities, or by any combinations of these methods. Earlier projects were generally based on channel works rather than on storage. With the higher dams which can be constructed with present engineering design and construction methods, reservoirs having sufficient capacity for flood control have become physically feasible. Such reservoirs can also be used for other benefits. Major flood control is now usually secured as a part of a multiple-purpose project based on full development of the stream.

Floods have been a material factor in California from its early settlement. The missions were located above the flood plains of their nearby streams. Early floods were mainly interruptions to travel. Early settlements in the Sacramento Valley were located adjacent to the Sacramento River and its larger tributaries in order to use river transportation. Such towns were subject to flooding in their earlier years. Floods in this valley also extended over much of the agricultural land. In the San Joaquin Valley land routes of travel were established near the eastern foothills in order to be nearer the mining areas as well as to keep above the overflow lands in the valley trough.

Early California Floods

Indian traditions indicate that a flood in the Sacramento Valley in 1805 inundated the entire valley floor and took many lives. Other floods occurred in 1825-26, 1846-47, 1849-50, and 1852-53. The largest reported early flood was in 1861-62.

Prior to reclamation work, floods on the Sacramento River spread over wide areas. In the floods of 1853 and 1862, the water extended from the site of Sutter's Fort in Sacramento to Davis with water three feet deep over the river bank at Sacramento and much deeper in the adjacent trough areas. In these floods the boats to San Francisco went across country from Rough and Ready Island to Antioch. The 1862 flood was the first one to bring large amounts of mining debris to the valley; lands near Marysville were reported to have been covered from one to six feet deep. Fresh-water fish were caught in San Francisco Bay for two months after this flood and outflow at the Golden Gate was continuous for several days.

The early floods in the San Joaquin Valley occurred in the same years as those in the Sacramento Valley but did less damage, as the settlements subject to overflow were more limited. The flood of 1867-68 was similar to that of 1861-62. On Christmas Eve 1867, buildings in Millerton were destroyed by a San Joaquin River flood. Trees brought down by this flood were spread over the plains near the present Skaggs Bridge and provided the logs for the operation of a sawmill for over a year.

In southern California, Father Juan Crespi reports a flood in January 1770. A flood in 1815 changed the course of the Los Angeles River from its outlet at Santa Monica to San Pedro Bay. The "great flood" occurred in 1861-62. In 1867-68 the San Gabriel River completed the formation of its New River channel, and in 1884 the Santa Ana River formed a new outlet to the ocean.

More Recent Floods

There are no direct records of the amounts of these early floods. Since direct measurements of stream flow have been secured, more definite records of the amounts of the flood flows are available. These recent floods are also within the period of larger settlements and improvements with their resulting increase in the amounts of the flood damage. Surveys of flood damage are now made following floods and much more information on their effect is obtained.

The flood of March 1907 was the first one in the Sacramento Valley on which quantitative results were secured. The total peak runoff of about 600,000 second-feet has not been exceeded by any later flows, although floods from some separate streams in the Valley have exceeded their 1907 record. The floods in January 1916 were particularly severe in San Diego County. The flood of March 1938 resulted in the loss in southern California of eighty-seven lives, with estimated damages of $80,000,000.

The most recent major flood was in December 1955. While some major floods have affected nearly the whole state, the flood of December 1955 was confined to northern California. Nearly 1,000,000 acres were inundated and over sixty lives were lost. Direct property losses were estimated to be about $200,000,000. The most severe damage resulted from the breaking of the Feather River levee and the inundation of Yuba City. This flood resulted from precipitation extending from December 18 to 24, 1955, with the total rainfall exceeding thirty inches over wide areas with some individual stations exceeding forty inches. The resulting peak flood runoff exceeded previous records on many streams in northern and central California. The loss of life and the damages which might have occurred from this flood on many streams were materially reduced by the operation of the flood-control reservoirs and other works which had been built.

Flood of December 1955 on Feather River after Levee Break
Yuba City and Marysville in Background

Courtesy of California Department of Water Resource

Courtesy of California Department of Water Resources

Feather River Flood of December 24, 1955.
Flooded Area Near Nicolaus

U.S. Bureau of Reclamation photograph

After the Flood Receded. Sacramento Valley

Rates of Flood Flow

The maximum flood flows that have been measured indicate the rates of runoff that occur on California streams. For streams draining the western slopes of the Sierras, peak flood flows have been from forty to over one hundred second-feet per square mile of water shed. These rates of peak flow represent a depth of runoff of from 1.5 to over 4 inches per day. However, such peak rates are not maintained for a full 24-hour period; maximum daily rates of flood flow have been from one to two inches depth per 24 hours. The equalizing effect of storage in Clear Lake is illustrated by the flood flows of Cache and Putah creeks; the rate of such flows in Putah Creek is over three times as large as the outflow to Cache Creek from Clear Lake. The maximum recorded peak flood flow on Eel River at Scotia on December 22, 1955, was 500,000 second-feet, equivalent to a depth of runoff of about five inches per day.

Early Flood-Control Works

At the time of statehood there was no state or federal agency available to undertake flood control. As settlement increased, flood-control works were initiated by local interests. As in other matters where there was no one else to assume responsibility, the early settlers built their own protective works. Lacking knowledge of the extent and frequency of the floods to be expected and limited in their methods of construction and financing, the earlier flood-control works were generally inadequate and gave, at best, only partial relief. These earlier works represent reclamation rather than flood control.

General Flood Conditions

In his first report, State Engineer William Ham Hall recognized the difference in conditions in the Sacramento and the San Joaquin valleys. He found an area of 2,750 square miles, equal to one and three-fourths million acres, subject to submergence north of Tulare Lake. The Sacramento River had floods inundating large areas nearly every year, while the San Joaquin River flooded only about one year in four.

There are also differences in the type of floods in the Sacramento and the San Joaquin valleys. The heavier precipitation on the Sacramento drainage area during the winter months results in high rates of runoff continuing for several days. These floods tax the channel capacities and overflow large areas of valley lands. Similar rain-storm floods occur on the San Joaquin River but have smaller rates of flow relative to the size of the drainage area as the amount of precipitation decreases from the north toward the south. Also the drainage areas of the San Joaquin Valley streams include more high mountains receiving their precipitation in the form of snow with its resulting delayed runoff.

A second type of flood flow occurs during the snow-melt period, generally from April 15 to June 15. This has a smaller peak rate but continues for a longer time. On the Sacramento drainage, the snow-melt flows do not produce flood flows in excess of the channel capacities. In the southern San Joaquin Valley the snow-melt floods cause the larger proportion of the flood damage, as they have no outlet of escape from Tulare Lake.

Floods in southern California are the result of the heavier winter storms. The relatively steep mountain drainage areas rise sharply from the adjacent valley lands. Runoff is rapid and large and brings a heavy load of eroded material. Prior to settlement, such floods spread over their debris cones and deposited their transported material. Settlement on such lands has resulted in very high rates of damage when floods occur in highly developed areas. Separate snow-melt flow is not a source of floods in southern California.

Federal Policies on Flood Control

Federal responsibility for flood control was not given legal recognition until relatively recently. Federal functions relating to streams were limited to matters affecting navigation until about 1916. While works had been built by the federal government which gave flood-control benefits prior to this date, they had been authorized on the basis of their benefits to navigation. In the earlier years consistent efforts were generally made to confine federal activities to matters directly assigned to the federal government. The present extent of participation in flood control by the federal government is another example of the expansion of federal activities into fields formerly considered to be the responsibility of local interests.

In 1916 Congress gave at least indirect recognition to federal responsibility for flood control by the creation of a Standing House Committee on Flood Control. The Flood Control Act of March 1, 1917, was the first federal statutory recognition of responsibility in this field. This act adopted plans for flood control on the Mississippi below the mouth of the Ohio. Local interests were required to contribute the rights of way used and half of the construction costs and to maintain the project after its completion. A navigation and flood-control project on the Sacramento River was included in the 1917 act, with the federal contribution limited to the parts of the project useful for navigation. This contribution was conditional on the appropriation by the state of an equal amount to that provided by the federal government for the joint works to be built. In addition, the state and local interests were to meet all costs for the levees needed for flood control. The state was to assume costs for maintenance after completion. This act also included provisions for examinations and reports by the Corps of Engineers on projects that were assigned to them by Congress. The Mississippi and the Sacramento rivers were the only projects on which plans had been completed at the time the 1917 act was passed.

Federal policy in relation to flood control was defined in the Flood Control Act of 1936. "....it is the sense of Congress that flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with States, their political subdivisions, and localities thereof; that investigations and improvements of rivers and other waterways, including watersheds thereof, for flood-control purposes are in the interest of the general welfare; that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected."

Investigations and improvements of waterways for flood control were placed under the jurisdiction of the War Department and water-flow retardation and soil-erosion prevention under the Department of Agriculture. The states or other responsible local interests were to provide the rights of way for each project, agree to meet any damages resulting from the project, and operate and maintain the project after its completion.

The 1936 Flood Control Act was amended in 1938 to provide that the United States would pay for rights of way for dam and reservoir projects or for channel improvement or channel rectification. This reduced the rights of way to be provided by local interests to the lands needed for the remaining types of flood-control works. Such remaining types are mainly levees to restrain floods within the existing river channels.

Further changes in flood-control policy were made in 1944. Plans for such projects, prepared by the Army Engineers, are now submitted to the states

concerned for comment before they are submitted to Congress. The 1944 act also authorized a number of flood-control projects in California, defined their principal features and specified the extent of local contribution that would be required.

Following the enactment by Congress of the 1944 Flood Control Act, the 1945 California Legislature adopted similar legislation defining the state's policy relating to flood-control projects authorized by the federal government. The state declared its primary interest in the control of flood waters, created a State Water Resources Board (now the California Water Commission) to handle the participation by the state in such projects, and approved the individual projects authorized by Congress. The Legislature also declared its intention to appropriate funds to pay the local contributions required for these projects.

Flood-control policy has changed since 1927 from one limited to indirect aid by the federal government through the guise of navigation to the complete construction of approved projects at federal expense without local reimbursement except for part of the cost of the rights of way. In California even this limited local contribution has been assumed by the state. These are very liberal terms for those whose property may be benefited by such flood-control works. While the federal government has preserved the appearance of only authorizing flood-control projects where the benefits exceed the costs, local interests now clamor for federal assistance if any damage may occur. The methods now used to estimate flood-control benefits, both direct and indirect, are liberal and projects may qualify which local interests would not approve if they had to meet a material part of the cost.

Flood-Control Projects in California

Flood-control studies in the Sacramento Valley were started in 1878 by the then created office of the State Engineer. Some works had been built but only partial protection was provided. In 1894 California established the office of Debris Commissioner to represent the state in matters relating to debris control. The commissioner was authorized to prepare plans for flood control in cooperation with the federal agencies. In 1910 dredging of the lower Sacramento River channel was begun cooperatively by the state and the federal government.

In early studies the Sacramento River flood flows expected were generally about 250,000 second-feet. For such flows, channel improvement types of projects were proposed. When the 1907 flood of 600,000 second-feet occurred, it was realized that this exceeded practical channel capacities and by-passes were added to the plans.

In 1911 the state passed the State Reclamation Board Act. With its 1913 amendments, this act created a State Reclamation Board to represent the state in flood-control matters in the Sacramento-San Joaquin Drainage District. This district included about 1,750,000 acres subject to overflow in the Sacramento and the lower San Joaquin valleys and their connecting delta.

A federal-state project was adopted in 1916, providing for flood control in the Sacramento Valley at an estimated cost of $33,000,000 to be provided one-third each by the federal government, the state, and the locally benefited areas. This is one of the earliest projects for flood control approved by Congress. This project has been expanded by including flood-control storage, but the basic by-passes were constructed and are still an essential part of the project.

The streams tributary to the lower San Joaquin Valley have winter floods of high rate but short duration which can be regulated by storage. The snow-

melt floods exceed the safe channel capacities in many years. As these snow-melt flows continue over the snow-melt period, larger storage capacities are needed for their control until they can be released without damage. While storage on these streams provides flood-control benefits, such control is usually constructed for other uses. A project for channel improvement above the mouth of the Merced River is now under construction.

Tulare Lake receives the surplus waters of the Kaweah, the Tule, and the Kern rivers and part of the flow of the Kings River. Some contribution is also received from smaller tributaries. The original conditions and the effect of irrigation on the inflow to Tulare Lake have been discussed in chapters I and VI. While originally Tulare Lake filled to its rim and frequently overflowed to Fresno Slough, depletion of its inflow has prevented such overflow for over seventy years.

To meet these changing conditions, much of the area of Tulare Lake had been reclaimed by levees so that only about 30,000 acres of the original area of about 200,000 acres which was subject to occasional flooding remained unreclaimed. In recent years, levees have been constructed within this sump. In some years no inflow may occur, in others the inflow may not exceed the storage capacity of the remaining unreclaimed area. In years of larger runoff breaks must occur in some of the reclamation levees to furnish relief from the accumulated flood waters. Such breaks cause damage to the reclamation works and to the crops submerged; they also prevent cropping of the lands during the time of their submergence. Water reaching the lake is pumped out for the irrigation of unsubmerged lands or is lost by evaporation so that the water received both does damage and is a benefit.

Flood-control reservoirs in Kings, Kaweah, Tule, and Kern rivers were authorized in the 1944 Flood Control Act. Those on the Kings and the Kern rivers have been completed and those on the Kaweah and the Tule rivers are under construction. In each of these projects the storage space will also be used for irrigation. The storage space required for flood control is determined by the volume of the snow-melt flows requiring regulation. As there is no danger of floods during the remainder of the irrigation season, the snow-melt water stored for flood control can be held to meet irrigation demands.

The Los Angeles County Flood Control District was created in 1915 and proceeded with projects to supply flood protection for its area until the federal government provided for federal flood-control aid. Extensive works have been constructed by both the U.S. Army Engineers and the district working on a joint program. State aid has been secured to meet the local participation in the costs of rights of way and relocation of highways.

The flood-control plan for this area consists of the regulation of floods by storage by major dams as near as practical to the area of origin of the flood flows; control of debris from eroding areas in debris basins; lining and bank protection to increase flood-channel capacities; storm drains for surface storm waters; spreading of flood waters for conservation; and the prevention, where practicable, of erosion.

For Los Angeles River the principal works are the Hansen and the Sepulveda retention basins and channel improvements along the main channel. For the San Gabriel River the principal works are the San Gabriel dams No. 1 and No. 2, and the Santa Fe and Whittier Narrows reservoirs.

Flood-control projects have also been constructed on the Santa Ana River. These include the Prado Reservoir and several levee and channel improvement projects on upper tributaries.

There are authorized federal flood-control projects on several other streams in California. Some have been constructed, some are under construction, and

some are waiting for appropriations for their costs. Since the acceptance of federal responsibility for flood control, local financing of flood-control projects has declined. An exception to the reliance on federal funds is the Nacimiento Reservoir, constructed on this tributary of the Salinas River by the Monterey County Flood Control and Water Conservation District, entirely at local expense. This reservoir is used for water supply and recreation as well as for flood control.

Flood Control of the Colorado River

Flood damages caused by the Colorado River in the Palo Verde and the Imperial valleys have been described in the discussion of the irrigation of these areas. Levees are, at best, an uncertain method of controlling floods on streams having as heavy a silt load as the Colorado River. Adequate flood control required the construction of sufficient storage to regulate the stream flow within the channel capacities.

Prior to the construction of Hoover Dam, the flow of the lower Colorado River at times exceeded 100,000 second-feet. At low flows the river channels filled with silt. At some locations, if floods occurred quickly without time to scour out the stream bed, flood stages might be relatively high for moderate rates of flow. If such flows continued, the river might actually drop, due to such scour. At the end of each flood period the river bed would refill.

The construction of Hoover Dam is described in chapter XII, as it represents a multiple-use project producing several benefits. For flood control it regulates the runoff of the entire drainage area of the Colorado River above Boulder Canyon. Floods on Bill Williams River are infrequent and flashy and can be regulated at Parker Dam. The only other major lower tributary is the Gila River. This stream and its principal tributary, Salt River, now have sufficient storage and use so that surplus and waste flows occur infrequently and in reduced amounts, giving only limited flood problems. The construction of Hoover Dam has removed the menace of floods from the Imperial Valley as well as providing other benefits.

Flood Control by Watershed Protection

The 1936 and later flood-control acts place flood protection by means of works to retard the runoff which produces flood damage in the Department of Agriculture. Such work may include fire control, improvement of vegetative cover, work on upper stream channels to reduce channel erosion, and flow-retarding practices on agricultural lands and alluvial fans. These practices have for their purpose reducing flood flows and erosion at their source. Some such projects in California have been authorized by Congress.

Such watershed-protection projects have not been in operation to a sufficient extent to demonstrate their usefulness in reducing runoff at times of maximum floods. They represent an auxiliary defense against floods rather than a replacement for other types of flood protection.

CHAPTER XI

Recreation and Related Uses of Water

Preceding chapters have discussed the different uses of water which represent the main purposes of usual water-development projects. There are other benefits that may result from such projects which, in the past, have generally been regarded as by-products. These include recreation and fish and wild life. These features should be considered in the project plans and included to the extent to which they are desired or may be feasible.

Recreation

The public interest in the recreational use of water projects, particularly where storage is included, has increased rapidly in recent years. Water sports, including water skiing, have become popular with the increased use of motor boats. Summer-cabin and camp sites adjacent to water areas have come into extensive demand. These increased recreational demands are the result of the improvement of highways, making recreational sites more accessible and more quickly reached for week-end trips, more time for recreation under shortened work weeks, and the production of motor boats in a large variety of sizes and prices. Recreation has now reached a status where

it is essential that it be considered in the plans for storage projects and provisions made for it insofar as it may not be adverse to the main project purposes.

The extent of recreational use of reservoirs in California is shown by the records of visitor days and numbers of motor boats sold in California. In 1957 over 800,000 visitor days were reported for the use of Isabella Reservoir on Kern River. Over 300,000 outboard motor boats were in use in the state in 1957; this number has been increasing rapidly. Use of recreation at reservoirs is not limited to the adjacent population. Registrations of boats at individual reservoirs show home addresses from all parts of the state.

The extent of the use of motor boats has led to some accidents and has resulted in statutory regulations at federal, state, and local levels. These regulations relate to registration with identifying numbers, speed limits, the supply of life preservers, and similar items.

The owner of a reservoir has responsibility for its proper operation and may be liable for damages resulting from his negligence. While it is essential that the owner have control of the use of the reservoir surface, it is not necessary that the owner should operate the recreational use of the reservoir. The owner operating the reservoir for its main uses may not have the staff or may not desire to operate the recreational facilities. These can be transferred to other public agencies or can be leased to private operators. The state is now financing small-boat facilities at some reservoirs meeting its requirements.

A recent report of the California Recreation Commission (Publ. 58-M2) contains information on the recreation facilities at 67 reservoirs in California. The operating agencies are usually public, but many differ from the agency owning the storage. The U.S. Forest Service operated about one-third of these recreational uses. The State Department of Parks and Beaches or an equivalent county agency operates the facilities at several reservoirs. Concessions may be granted to private operators under permits or contracts. Where there is recreational use of a reservoir, there is usually a demand for boat rentals, gas and oil service, and refreshments. Such services are usually provided through private operators.

Swimming is permitted in reservoirs used for recreation, except where the storage is used for municipal purposes. For municipal reservoirs, public health rules do not permit the so-called "body contact" uses, such as swimming and water skiing. For all reservoirs used for recreation, boating is permitted. The reservoir area may be zoned for different uses, with water skiing and speed-boat use separated from the swimming and fishing areas.

The fees charged vary. For some reservoirs a yearly fee for each boat may be charged, or a rate for each day may be used. Launching and docking charges may be made where these facilities are provided. Fees may be charged for camping, trailer camp, or picnicking where water, tables, and sanitary facilities are provided.

For reservoirs of larger size and convenient access the demand usually results in the establishment of commercial boat docks. There are several such docks on Almanor, Shasta, and Big Bear. These operate boat rentals, separate motor rentals, sell gas, oil, bait and tackle. Nearly all have launching facilities for private boats and a few have lodging or trailer space.

No specific basis has been established on which to define the value of recreation in a water project. The willingness of voters to provide funds for reservoir construction where recreational uses are included and the extent to which public recreational facilities are used reflect the widespread recog-

U.S. Bureau of Reclamation photograph

Recreational Use of Millerton Lake, at Friant, Central Valley Project

U.S. Bureau of Reclamation photograph

Recreational Camping on Shasta Reservoir, Central Valley Project

nition of the value of recreation. In some cases where charges are made for the use of the recreational facilities, a basis may be secured for evaluating the extent to which recreation can help meet storage costs. The value to an individual or a family per day spent in water recreation is intangible. The price the users may be willing to pay to secure such recreation is one measure of the users' own appraisal of its value.

In general, reservoirs have not been operated to secure maximum revenue from recreation on the basis of "what the traffic may bear." Public reservoirs have generally been operated with nominal charges or with rates based on returning the costs of the supervision and facilities which have been provided. Policing and clean-up are principal costs of operation. Boat ramps, comfort stations, and access roads are usual costs of construction. Where there may be a demand for cabin sites around a reservoir, long-time leases or sales of lots may be used.

Reservoirs used to regulate stream flow fluctuate with their varying inflow and draft. Reservoirs which may be emptied provide less attractive recreational uses than those which remain at least partly full. Where it is desired to maintain a recreational water surface, minimum pools are provided in the storage plans. The incremental cost of providing the additional storage capacity needed for an adequate minimum pool is generally a small percentage of the total reservoir cost. Such minimum pools preserve the fishing in the reservoir and can be made to furnish adequate space for water-surface sports.

For federal projects, recreational uses may be included in estimates of project benefits. Congress has made costs allocated to recreation nonreimbursable in some recent projects having other main usefulness. To date, the costs allocated to recreation have been based mainly on the added costs resulting from its inclusion in project plans.

The California Legislature has recognized the public interest in recreational use of reservoirs. Legislation requires opening reservoirs for recreation, except where the safety of public water supplies would be affected. The 1957 Legislature also provided that the state could pay costs of water-development projects properly allocated to recreational benefits of statewide interest incidental to the main-project functions. Before appropriations for such payments are made by the Legislature, reports are required from the Department of Water Resources on the project. A.B. 140 (chap. 2047), passed by the 1959 Legislature, provides that all plans for state projects now presented to the Legislature by the Department of Water Resources must include provisions for facilities necessary for public recreation and for the preservation and enhancement of fish and wild-life resources that the Department finds to be justifiable in terms of state interest and feasible as a nonreimbursable cost of the project. Such nonreimbursable costs for recreation are limited to the recreational features of statewide interest.

Title to private lands in reservoir sites may be acquired in fee simple or an easement to flood may be secured. Formerly, easements were used for some reservoirs, with the former owners retaining uses of the land not in conflict with the easements. With the present extent of recreational demand, it is essential that the owner of the reservoir have control of the access to and use of its water surface in order to be able to police its use and to regulate recreation. This has made it necessary for the owners of reservoir projects not only to acquire title to the submerged area plus a reasonable access margin needed for other reservoir uses but also to acquire additional areas for recreational use. Such areas are needed for camping, boat landing, picnicking, and, where suitable, cabin sites. Control is most easily secured if

adequate area is acquired at the time of reservoir construction. The lands to be acquired can be defined in the reservoir plans. They should include the areas to the high-water line plus some additional height for access and policing (an additional ten feet in elevation has been used by some agencies), with the resulting contour squared out to include the nearest forty-acre land areas. The additional area needed for recreation should also be acquired. To define such recreational areas a recreational plan should be included with the reservoir plan.

Flowage rights on public lands may be acquired for use by local agencies under such terms as Congress has made available. Earlier acts provided for grants of the public lands within the meander of the high-water line plus a small margin. Usual present practice is to issue licenses or permits for the use of the public lands needed; these are equivalent to easements.

More attention is now being given to making full use of the recreational potential of both existing reservoirs and in plans for future construction. The extent of the use which is made of such facilities justifies this practice. It can be expected that this demand for recreational use will continue. Recreation can be a helping partner in storage projects and the recreational opportunities can be used to assist other project uses.

Fish and Wild Life

The public interest in the protection of fishing was shown by the action of the California Legislature as early as 1852 in a statute making the use of weirs, stop nets, and other methods of obstructing the salmon run public nuisances. No one except the Indians were allowed to fish with seines or nets in July, August, November, and December.

Use of water for fish and wild life is closely related to its general recreational use but is usually separately considered. The improvement of fishing resulting from water projects is mainly a recreational use rather than an aid to commercial fishing. Dams creating barriers to spawning runs may affect both recreational and commercial fishing.

Protection of existing fishing conditions and demands for their improvement have been prominent factors in numerous projects. Fear of the loss to fishing on the Klamath River resulted in 1924 in the passage of an initiative measure by the California voters banning any dams on this stream below the mouth of Shasta River.

Some early projects were built which diverted the entire stream flow at low-water stages. In recent years new projects have generally been required to pass a minimum natural flow to maintain fish life in the stream. The fishing interests have generally been represented officially by the State Department of Fish and Game. This department reports to the Water Rights Board its conclusions regarding the effect of proposed projects on fishing with recommendations regarding limitations that should be included in water-right permits to protect fishing interests. The permit terms may include provision for minimum releases to maintain fish life.

For some projects the Department of Fish and Game has not limited its demands for releases of water to the maintenance of past minimum flows but has asked for releases of stored water for the improvement of fishing. While there may be some support for maintaining past minimum flows for fishing, seeking increased flow at the expense of projects planned for other purposes is a very different matter. While costs allocated to fish and wild life are nonreimbursable in federal reclamation projects and may be contributed by the state in California projects, to date only limited parts of the total costs have been allocated to fishing. If provision of flow for fish pays its own way in

U.S. Bureau of Reclamation photograph

Intake of Delta-Mendota Canal, Central Valley Project. Fish-Collecting Facilities, Showing Training Wall and Prime Louvre Structure

California Department of Fish and Game photograph

Fish Screen on Canal on Cosumnes River Showing Float Which Opens Safety Gate in Case of Loss of Head

project costs, the main question then becomes the balancing of over-all benefits from the water required for fish and the value of the use of the same water for other project uses.

The California Department of Fish and Game presented extensive testimony in the recent hearings on applications to appropriate water of the San Joaquin River for storage at the Friant Reservoir of the federal Central Valley Project. These hearings were conducted by the State Water Rights Board, about twenty years after the federal government had built this project at the urging of the state and after contracts with public agencies of the state had been made for the delivery of the water to be appropriated. Even at this late date the State Department of Fish and Game contended that permits for storage at Friant should require the release of stored water to maintain fish in the San Joaquin River in amounts in excess of the preproject flow in some portions of the river. Such releases would have reduced the supply available for delivery from the project. While this contention was by the Department of Fish and Game, this procedure illustrates the need for an overall state policy which can prevent conflicting positions by different divisions of the state government. The state is one entity and if one branch of state government has approved contracts made by irrigation districts for purchase of project water, the state should not later take a conflicting position through the action of some of its other departments.

California statutes make it unlawful to prevent or impede the passing of fish up or down stream. The Department of Fish and Game examines dams and may order the owner to install a fishway if it is needed. The Department may accept a fish hatchery as a substitute for a fishway or the owner of the dam may plant substitute fish secured from other sources. The principal interference with commercial fishing has been where dams have prevented the salmon run to their upper spawning areas.

It is now usual to stock reservoirs artificially where minimum storage will be maintained. Such stocking can be a substitute for the previous stream fishing or it may be an addition to the natural fishing. The cost of such stocking is borne by the state. The types of fish used are selected on the basis of their adaptability to the temperature and other conditions in the reservoir.

As the benefits resulting from the use of water for fish are intangible, widely varying claims can be presented regarding its value. Some of such claims have been based on the cost to the sportsman per fish caught multiplied by the estimated catch. This basis can give remarkable results where the fisherman may come from district areas and the fishing is poor.

Loss of fish in a stream may occur by their entrance into the channels used to divert water for other uses. California has long had statutes requiring screening of such intakes, although the conditions and terms have varied. Prior to 1952 screens were required to be installed at the cost of the canal owner under plans approved by the state. For these conditions the canal owners were interested in a type of screen which would be approved and which could be installed at minimum costs with minimum interference with the diversion. The Department of Fish and Game, paying none of the cost, naturally preferred screens 100 percent effective. The results were unsatisfactory to all interests. In 1952 the Legislature provided that the state should pay one-half of the cost of any screen required by the state for diversions of over 250 second-feet and all of the cost for smaller diversions for all uses except those for power. This legislation has materially improved past conditions.

Any fish screen ordered to be installed by the Department of Fish and Game

is to be reasonably adequate to prevent fish from entering the diversion but is not to impede entry of water unnecessarily. If the owner and the department cannot agree on the type, size of mesh, and location of the screen, the matter is submitted to the State Water Rights Board which decides the points at issue. By-pass water may be required to return the fish intercepted by the screen to the stream. One type of screen now used consists of a steel plate having 5/32-inch holes on 3/16-inch centers with wiper bars operated to keep the screen clean.

The "wild life" used in combination with the "fish" in relation to water matters is represented by the water fowl which may use water areas for nesting or for stops on their seasonal migrations. Duck clubs flood areas in an effort to attract wild fowl. The state and the federal government maintain refuges both as an aid to the agreed fly-ways and for public shooting. Wild fowl are an international issue, as the United States has treaties with Canada defining conditions to be maintained on certain migration routes. While water for fish is a nonconsumptive use unless it results in waste below the last points of diversion, duck ponds consume water by evaporation and by transpiration of the induced vegetation.

The limited benefits resulting from water used in duck ponds were recognized in early statutes. An ordinance of Orange County prohibiting such use of ground water has been upheld by the courts as a reasonable exercise of the police power.

The U.S. Bureau of Reclamation has sold some water for use in duck ponds on the San Joaquin River, but the waters so sold have been those in excess of project needs. Here, again, widely varying claims can be made regarding the value of the use of water for ducks. Returns per acre-foot of water used, based on the cost per duck to the hunters, can give results in excess of the value of the use of the same water for other purposes.

CHAPTER XII

Multiple-Purpose Projects

The term "multiple-purpose projects" is used in this chapter to include projects beyond the scale of local effort but less than statewide in scope. There are also local multiple-purpose projects, such as those for power, irrigation, and flood control. This chapter describes the comprehensive multiple-use projects for the Central Valley and for southern California. It stops short of the projects planned to convey water from northern California to southern California. These are discussed in chapter XIII. There are no generally accepted definitions of the descriptive terms used for these types of projects. The basis used here has been adopted as a matter of convenience.

In the preceding chapters the use of water for different types of single-purpose projects has been separately discussed. Until recent years, California water projects have been built primarily for some separate use of water. Early projects used local water supplies to meet local needs. Such projects still represent the major support for the present development.

There has been a recognition, from the early days of the state, that larger projects would be needed to make full use of the water resources and that such projects would include the transfer of water from areas of excess sup-

ply to areas of deficiency. Many of the recently built local projects were beyond the capacity of their local areas in their early years. It has been recognized that comprehensive projects would have to wait until the growth of the demand and of the supporting population justified their construction. The state has not lacked foresight in these matters. It has timed its actions to the progress in the development of the state.

Large-scale water development to date has been centered mainly on the needs of two principal areas and sources. The Central Valley, with its two principal streams, the Sacramento and the San Joaquin rivers, is a natural geographical area for coordinated development. The use in California of water from the Colorado River is the second major development. Plans for the multiple use of other smaller basins have also been made.

In recent years more extensive projects have been planned in which water would be conveyed from areas of excess supply to distant areas of deficiency. The Feather River Project is the furthest advanced of projects of this type. These statewide plans are discussed in chapter XIII.

Multiple-Use Plans for the Central Valley

Early Reports

The state became interested in the development of the Central Valley at an early date. In 1866 a survey of a canal on the west side of the Sacramento Valley from the mouth of Red Bank Creek for 180 miles to the Montezuma Hills was authorized.

The first engineering report on the Central Valley, which can be described as comprehensive, was that made by the Alexander Commission in 1874. This was a federal commission which Congress had authorized with an appropriation of $5,000 for its work. The Commission was instructed "to make a full report to the President on the best system of irrigation for said valleys with all necessary plans, details, engineering, statistical and otherwise." The resulting report represented full value in relation to its costs. When the limited engineering records then available are considered, this Commission accomplished more than could have been expected. No later reports of similar scope have accomplished so much for so little cost.

The map accompanying the Alexander report shows a west-side canal in the Sacramento Valley from Red Bluff to Fairfield. On the east side of the Sacramento and the San Joaquin valleys short canals using each stream were proposed.

This commission recognized that the plans proposed were beyond the financing ability of the then population but that "time will bring this about, but probably fifty years will be necessary to complete it." In fifty years, local development had reached the point where studies were actively under way for a general plan of development for the Central Valley.

It was recommended that government aid should be provided for surveys and plans and for stream measurements. The water and land should be joined with perpetual water rights. As the lands would be benefited manyfold, they should pay the cost. The state and the counties would be directly benefited by the appreciation of land values and increases in taxes and should aid. However, caution was urged in extending state and county aid; the use of regulated private companies operating under franchises with agreed costs for water until they were taken over later by the landowners was recommended.

In his report to the Legislature in 1880 the State Engineer, William Ham Hall, concluded that the state should not construct irrigation works but should foster development by establishing a business basis for construction by the

local areas to be served. Essential to such a business basis are secure titles to the use of water with control of the streams resting in the state and the attachment of water rights to the land. The areas irrigated should bear all of the costs of their irrigation and the works should be in the control of the irrigators. The state should interfere with such internal control only to the extent that might be needed to prevent waste. Irrigation by public districts should be a higher use and allowed to condemn water from other uses except from municipal use. Navigable streams should be named and should be regulated so as to control the diversions for irrigation. Riparian rights should be a preferred privilege for domestic and stock uses. On many of these items the soundness of the advice has been demonstrated by later experience.

For nearly forty years after 1880 public interest in water development in the Central Valley was active but was directed toward policies relating to titles to the use of water and laws under which local areas could construct their local irrigation systems. This was the period of conflicts with riparian rights, the development of the irrigation district form of organization, and the passage of the water commission act.

A general outline of a plan for the coordinated development of the Central Valley was proposed by R. B. Marshall, Chief Geographer of the U.S. Geological Survey, in a public letter dated March 16, 1919. Marshall proposed a reservoir at Iron Canyon on the Sacramento River with a grand canal on each side of the Sacramento Valley. The west-side canal would extend into the San Joaquin Valley nearly to Dos Palos; the east-side canal would reach the San Joaquin River near Herndon. Lands below elevation 350 feet would be served by these canals. A higher canal would start at the Stanislaus River, pick up water from the streams to the south which it would cross, and extend to and around Tulare Lake, serving lands to an elevation of 400 feet. A still higher canal would start at the San Joaquin River and extend around the valley and northerly to Dos Palos. Kern River water was to be taken to Los Angeles.

The project proposed by Marshall, when investigated, was found to have higher costs than the projects which have become the present Central Valley Project. The Marshall Plan was supported vigorously by its advocates and had some effect in stimulating public thinking on the use of the water resources of the Valley.

The State's Central Valley Project

Public recognition of the need for a coordinated plan for the use of the water resources of the Central Valley had begun to develop prior to 1920. The expansion in ground-water draft in the southern San Joaquin Valley at the close of World War I caused public concern regarding the ground-water depletion which had occurred in areas of heavy draft and limited replenishment. Some means of securing additional water for such areas was sought. Local water supplies were inadequate and the cost of bringing in water from distant streams was beyond the resources of such local areas. Ground-water studies by the State Engineer's office, reported in the early 1920's, showed the extent of the then ground-water depletion. Unless supplemental water could be secured from some outside source, much highly developed land would eventually face abandonment when its increased pumping lift would make pumping unprofitable. The public interest which was aroused by the situation in these areas furnished the support for undertaking investigations of the water resources of the state and for the preparation of a plan for their use.

Another situation which attracted attention to the water conditions in the Central Valley was the increase in the intrusion of salt water into the Delta in the late summer months when diversions depleted the tributary inflow of

fresh water. Extensive investigations were made, beginning in 1924, of a physical structure to prevent such intrusion. This Salt Water Barrier, as the proposed dam across Carquinez Straits came to be known, was found to be physically feasible in its construction features but to have doubtful effectiveness in the prevention of the intrusion of brackish water into the Delta. Later studies indicated that salt-water intrusion could best be controlled by maintaining a sufficient flow of fresh water from the Delta to repel the entrance of salty water. Proposals for a salt-water barrier at different locations have continued to be advanced, although engineering reports on their costs and effects have recommended against their construction. The U.S. Army Engineers now have in progress a model study of San Francisco Bay and its inflow channels which it is hoped may furnish results relating to the effect of any bay barrier which will be accepted.

The Legislature in 1921 authorized the State Engineer "to determine a comprehensive plan for the accomplishment of the maximum conservation, control, storage, distribution and application of all the waters of the state, and to estimate the cost of constructing dams, canals, reservoirs or other works necessary in carrying out this plan." From 1921 to 1929 the state appropriated nearly $1,000,000 for such investigations. Similar work has been continued by the state since 1929. The undertaking of the Central Valley Project by the federal government in 1935 did not eliminate the state's interest nor its responsibility for the development of its water resources.

The Hoover-Young Commission was a joint federal and state group which made a report on the water resources of the state in December 1930. It recommended construction of the Central Valley Project and the diversion of Colorado River water to the southern California coastal area. It reported adversely on a salt-water barrier structure.

The results of the investigations from 1921 to 1930 were published from time to time in several bulletins of the State Division of Water Resources. The conclusions were brought together in 1930 in Bulletin 25 of this Division in the form of a recommended State Water Plan. For the Central Valley, storage on the Sacramento River and conveyance of water from the Sacramento Valley to the southern San Joaquin Valley by means of pumping up the valley to Mendota and an exchange of water there (so that the flow of the San Joaquin River could be stored at Friant for conveyance and use on higher lands) was proposed for immediate construction. Plans for the complete development of the waters of the Central Valley were outlined. Bulletin 25 also discussed the coordinated use of water in other parts of the state. Recommendations for initial projects in the ultimate coordinated plan were limited to the initial Central Valley Project and the Colorado River development.

This initial Central Valley Project had an estimated cost of $158,000,000. For financing with 4 percent bonds amortized over fifty years, the revenues, as then estimated, from the sale of water and power would meet the costs.

The State Water Plan, as described in Bulletin 25, was presented to the 1931 Legislature. No direct action looking toward its construction was taken by this Legislature. A California Water Resources Commission was authorized to give consideration to the legislation and financing that would be needed to carry out the plan. A joint legislative committee was also appointed. These two groups made separate reports; both approved the engineering features of the Central Valley Project and submitted a proposed constitutional amendment and legislation designed to enable the state to carry out the construction of the project.

The next Legislature passed the Central Valley Project Act of 1933, which authorized the construction of the project by the state. A State Water Project

Authority was created to administer this act. Financing by the issuance of revenue bonds up to $170,000,000 was also authorized; charges on these bonds were to be met entirely from project revenues without any general liability on the state. This act was approved at an election on December 19, 1933, and became effective in January 1934.

The 1933 Central Valley Project Act specified the units to be included in the Central Valley Project. These were a dam on the Sacramento River near Kennett (now known as Shasta Dam); a transmission line from this dam to near Antioch; a canal from the Delta along Suisun Bay to the vicinity of Martinez (now Contra Costa Canal); channels to carry Sacramento River water across the delta and up the San Joaquin River (now the Delta Cross Channel and the Delta-Mendota Canal); a dam on the San Joaquin River at Friant (now the Friant Dam); a canal northerly from Friant to the Chowchilla River (now the Madera Canal); a canal southerly from Friant to the Kern River (now the Friant-Kern Canal); and such other units as the Water Project Authority might add which were consistent with the objects of the act.

Efforts were made to finance the project by means of the revenue bonds authorized by the act. These efforts were unsuccessful, due in part to the general economic conditions at that time, and, more particularly, to the fact that the only security for payment of the interest and principal would be the revenues of the project. Efforts were next made to secure finances by means of the then available terms of the loan and grant procedure of the federal government. To aid in relieving unemployment, the federal government had provided funds for the Public Works Administration with which it could finance approved projects on the basis of a grant of 30 percent and a loan of 70 percent of the cost. These efforts were also unsuccessful. To 1935 the State Water Project Authority had not found means by which it could construct its Central Valley Project.

The Federal Central Valley Project

During the depression of the 1930's, Congress made available to the President funds which he could allocate to projects for the purpose of creating employment. In September 1935 the President made an allotment from the Emergency Relief Act funds for the start of the Central Valley Project. These funds were assigned to the Bureau of Reclamation of the Department of the Interior, and the Bureau began work immediately. The Secretary of the Interior made a favorable finding on the feasibility of the project in December 1935.

The first Congressional action relating to the Central Valley Project was the appropriation of $12,000,000 in the Rivers and Harbors Act of August 30, 1935, for the estimated flood-control benefits of the project. A complete reauthorization of the project was made in the Rivers and Harbors Act of 1937. This provides that the project shall be operated for (1) river regulation, navigation, and flood control; (2) irrigation and domestic purposes; and (3) generation and sale of power as a means of aiding and assisting financially the other preferred uses. In 1940 the authorization was enlarged to include the construction of lateral canals in local areas. The project authorized is the equivalent of the initial Central Valley Project approved by the voters of the state in 1933. To distinguish the project which Congress has authorized from the ultimate coordinated or comprehensive project for the entire valley, the project which has been under construction since 1935 has generally been designated as the authorized Central Valley Project. Since 1937 Congress has authorized additions to the initial project.

Both the Emergency Relief Administration funds and later appropriations

by Congress were made available to the U.S. Bureau of Reclamation to be expended in accordance with the provisions of the reclamation law. The acceptance and use of these funds automatically removed the control of the project from the state to the federal government where it has since remained. While the state has cooperated with the federal agencies in many matters, the primary responsibility for the construction of the project and its management rests with the U.S. Bureau of Reclamation. The federal authorization describes the same project covered by the state act, but the federal agency is not bound by the terms of the 1933 state Central Valley Project Act. Some changes have been made in the project as planned by the state.

The functions which the initial Central Valley Project as then authorized and partially constructed would provide included the following (H.D. 146, 8th Cong., 1st Sess., 1947, p. 10).

(a) Navigation with a minimum flow of 5,000 second-feet above Sacramento except for certain months in extremely dry years.
(b) Flood control by storage at Shasta and Friant reservoirs.
(c) Salinity repulsion by the maintenance of a minimum flow of approximately 3,000 second-feet at Antioch.
(d) Irrigation and municipal use with an average annual yield of 1,258,200 acre-feet of Class I and 768,500 acre-feet of Class II water.
(e) Electric power from Shasta and Keswick hydroelectric and Delta steam electric plants with assured capacity of 419,000 kilowatts producing 2,121 million kilowatt hours of firm energy per year.
(f) Recreation and fish protection.

This report included the following comment (p. 7): "The project functions of salinity repulsion, fish protection and recreation are not specifically mentioned in the legislation. It is concluded that salinity repulsion may be classified as a supplemental irrigation function, and fish protection and recreation as miscellaneous purposes ...."

The water supply for irrigation in the upper San Joaquin Valley is secured by an exchange of the water brought from the Delta by the Delta-Mendota Canal for the San Joaquin River water previously diverted at or below the Mendota Pool; from the purchase of the pasture rights in the less dependable flow of the San Joaquin River; and from the unappropriated flow of the San Joaquin River. The parts of the project's water service have been designated as Class I water for the dependable supply and Class II for the flood waters. These changes would have been within the scope of the state's project and would probably have been made if the state had been successful in constructing its project. The irrigation service to be provided remains essentially the same as that planned by the state.

The federal Central Valley Project has proceeded actively since 1935. The first major construction undertaken was the Friant and the Shasta reservoirs. The Contra Costa and the Madera canals were also begun soon after their authorization. Water rights on the San Joaquin River were purchased and an exchange agreement was made with the owners of the crop-land water rights on the river. When World War II resulted in the stopping of all construction, except that directly useful to the war effort, these works were ready for partial operation. Two of the power units at Shasta Dam had been installed and were operated during the war.

At the close of the war, Congress increased the annual appropriations for the project and more active construction was resumed. The inflation after the war resulted in a large increase in costs and the estimated total cost of the authorized project was increased from time to time to meet changes in plans and increases in unit prices. By 1947 the project was about half com-

pleted at costs to that date about equivalent to the original estimate of the total cost. The revised estimate of the cost to complete the then authorized project had been increased by 1947 to $384,000,000.

The early plans of both the state and the Bureau of Reclamation were based on the construction of main canals only, leaving the construction of the local canals distributing water within each unit area of the project to be handled by the local organizations. In 1940 Congress authorized the construction of such local distribution systems as a part of the project, with the repayment for their costs to be made over a forty-year period without interest. The costs of such lateral systems are additional to the costs of the general features of the project. Each contracting unit will repay the costs of the distribution system constructed for it by the Bureau of Reclamation. Some units have constructed their own distribution systems. The repayable costs of the distribution systems under contract to be built by the Bureau of Reclamation for eleven contracting districts were about $55,000,000 on June 30, 1957.

Additions to Initial Project

The initial Central Valley Project has been enlarged by other units which have been authorized for construction and integration with the initial project. These additions have materially changed the scope of the project. Its principal purpose is still the irrigation of lands in the San Joaquin and the Sacramento valleys.

The American River and the Trinity River divisions will provide additional water and power. These have been authorized and are being constructed. The Sacramento Canals Division will deliver water to lands in the Sacramento Valley. This has been authorized and construction has been started. The San Luis Unit has been recommended for authorization and is now before Congress.

Storage on the American River at Folsom, with a capacity of 355,000 acre-feet, was authorized for construction by the U.S. Army Engineers for flood control in 1944. This project was reauthorized in 1949 for joint construction by the U.S. Army Engineers and the Bureau of Reclamation, with a storage capacity of 1,000,000 acre-feet. The Army Engineers constructed the dam and define its flood-control operations. The Bureau has constructed and operates the power features of the project. The Bureau also plans to construct canals to irrigate lands both north and south of the American River with water from the American River regulated by the storage space at Folsom not required for flood control. Storage space is reserved for flood control during the flood-flow season; such flood-control space may be filled after the time when floods may occur has passed. Water to fill the flood-control space will be available in many years from the later snow-melt flow. The cost of Folsom Reservoir, built by the Army Engineers, was about $62,000,000. The total cost of the American River Division of the Bureau, mainly for power facilities, was $54,742,000. These facilities have been constructed and are in operation. These Bureau costs include about $6,000,000 for the construction of the Sly Park Dam and conduits for the El Dorado Irrigation District. Additional storage on the North Fork of the American River is planned at the Auburn site with a capacity of 1,000,000 acre-feet.

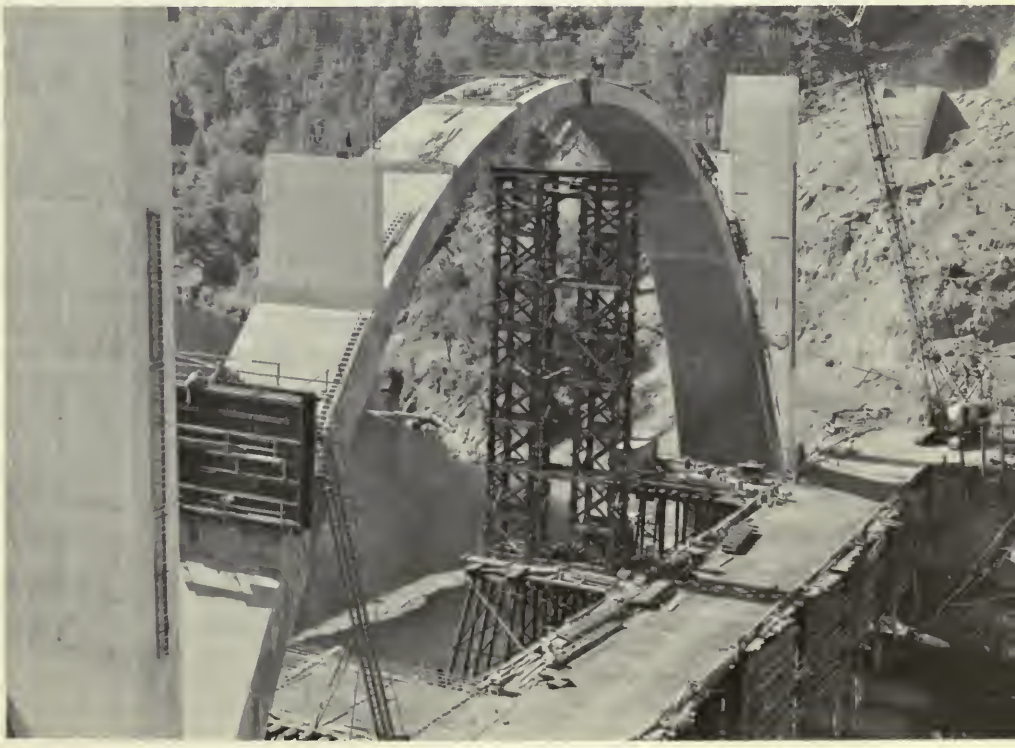
The Trinity River Project is also under construction. It will store water on Trinity River for diversion to the Sacramento Valley and use there by the Sacramento Valley canals, and for pumping from the Delta. Power will be generated from the fall of this water from its storage to the Sacramento Valley. This project has been in the public eye as a result of the controversy over who should construct the power features. The Secretary of the Interior reported that substantial savings to the federal government could result from

U.S. Bureau of Reclamation photograph

Contra Costa Canal of the Central Valley Project

Construction of Railroad Bridge Over North Fork of Feather River on Relo cation of Western Pacific R.R. Around Oroville Reservoir Site. Sept. 1959

Courtesy of California Department of Water Resource



construction of the power facilities by the Pacific Gas & Electric Company, which had offered to lease the use of the project's falling water and to finance the power-plant construction. Congress has recently authorized their construction by the federal government. Apparently, political considerations outweighed economic advantages to the federal government in this action.

The authorized Trinity River Division of the Central Valley Project consists of a reservoir on Trinity River near Fairview, with a capacity of 2,500,000 acre-feet; the Clear Creek tunnel, nearly eleven miles long, to the Sacramento Valley; and a total power installation of 400,000 kilowatts. The Bureau of Reclamation reported that the estimated total cost of $220,000,000 should be allocated $157,000,000 to commercial power, $62,000,000 to irrigation, and $390,000 to municipal and industrial use, with the remainder allocated to nonreimbursable uses for fish, wild life, and recreation. An average of about 700,000 acre-feet per year of Trinity River runoff will be diverted, which, when coordinated with the Central Valley Project system, would provide 1,190,000 acre-feet per year for additional use in the Central Valley Project. This supply would make available 665,000 acre-feet to meet the needs of the Sacramento Canals on 205,000 acres and 525,000 acre-feet to be used on other lands in the Central Valley, such as those in the proposed San Luis Unit.

The feasibility of the Trinity River Division was derived from the operation of the entire Central Valley Project, including the Trinity River Division. On this basis, the entire Central Valley Project would meet its repayment requirements by the year 2013 and have an earned surplus from power of $170,678,000.

San Luis Unit - Central Valley Project

The Bureau of Reclamation made a feasibility report in 1955 on an addition to the Central Valley Project to serve lands on the west side of the San Joaquin Valley extending from near Dos Palos to Kettleman City. A net area of about 440,000 acres would be irrigated. The estimated cost for the proposed federal construction was $229,000,000 with $170,000,000 additional required for the local distribution system. Water would be pumped from the Delta by the existing Tracy pumping plant and conveyed through the present Delta-Mendota Canal to San Luis Creek, where it would be partly used directly and partly stored in the San Luis Reservoir. The water supply would be secured from present surplus waters in the Delta, supplemented, when needed, by storage release from other reservoirs of the Central Valley Project.

The feasibility of the San Luis Unit was based on adding its costs to the remainder of the Central Valley Project and comparing the over-all costs and returns. Such an enlarged Central Valley Project would have a total estimated cost of $988,000,000, of which $78,000,000 would be nonreimbursable. The allocated costs and repayments for the reimbursable features were as follows:

Function	Cost Allocation	Net Operating Revenues to Year 2014: For Repayment	Net Operating Revenues to Year 2014: Interest and Earned Surplus
Irrigation	$696,149,000	$493,725,100	
Commercial Power	195,956,000	372,446,000	$137,198,300(1)
Municipal and Industrial Water Service	18,612,000	44,545,900	11,028,400(2)
Total Reimbursable	$910,717,000	$910,717,000	

(1) Includes $38,419,400 interest and $98,778,900 in earned surplus.
(2) All interest—not applied toward repayment.

These results represent an estimate that, for the enlarged Central Valley Project, power, municipal, and industrial service could repay all of their allocated costs, including interest where charged, and could also provide nearly $200,000,000 to meet the expected deficit in irrigation repayment.

No similar balance of allocated cost and expected revenues is presented in the report for the San Luis Unit separately. As this Unit would make joint use of facilities already constructed for the present Central Valley Project, a segregation of its costs would be difficult to make. The report states that a water rate of $7.50 per acre-foot used will be required for the San Luis Unit. The estimated annual costs of the Unit are $8,813,000 and the estimated sales are 1,126,000 acre-feet, giving an income nearly equal to the costs at this price per acre-foot. These costs relate to the main canals only and do not include the distribution system.

The cost to the landowner, for Bureau of Reclamation financing of construction costs, for the distribution system, drains, deep wells, capital, and operating costs, was found to be $19 per acre per year. With an average use of 2.17 acre-feet of project water per acre, the annual cost to the landowner for purchase of project water would be $17 per acre. The annual payment capacity for water of these lands was estimated to be $56 per acre. These total water costs of $36 per acre would take 65 percent of this total payment capacity. It has generally been found difficult to collect this large a percentage of the payment capacity for total water costs, as the landowner requires an incentive for his operations which may involve his use of capital for land values and crop operations of similar magnitude to the costs of providing the water supply.

The above results are based on federal financing of the distribution system. Such federal financing would have about $135,000,000 lower costs to the landowners for a forty-year amortization period than similar costs for financing at 4 percent interest. Costs to the local landowners would be reduced by this amount if the distribution system should be built by the Bureau of Reclamation on interest-free terms. The similar reduction in cost to the local landowners from federal construction of the main canal works would be about $180,000,000. These results illustrate the extent of the benefit to the landowners if the entire project should be built under present federal interest-free financing. Over a forty-year repayment period the total interest reduction under federal terms, compared to financing at 4 percent interest, would be about $700 per net acre to be irrigated. As the federal government is a continuing borrower, any funds used for construction of interest-free projects result in a cost to the federal government of the amount of interest it has to pay on the funds used for such projects. For an interest rate on federal borrowing of 3 percent, the federal subsidy to the San Luis area over a forty-year period of repayment would be about $240,000,000 or over $500 per net acre to be irrigated. Under the terms of the Reclamation Act, there may be an additional ten-year development period, also interest-free, which, if granted to this project, would increase the federal subsidy by about $160,000,000, equal to about $350 per net acre irrigated as compared to financing at 4 percent interest. At present, interest rates on federal bonds are increasing.

The area to be served by the proposed federal San Luis Unit of the Central Valley Project is also a part of the service area of the state's proposed Feather River Project. The interrelations of these two projects are discussed in chapter XIII.

Cost Allocations

A cost allocation for the then Central Valley Project was made by the Bureau of Reclamation in 1947. The project at this time included the same fea-

tures as the initial project. The changes which had been made in the state's project were the result of further investigations. All costs had been increased by inflation. The estimated cost of the project in 1947 was about 225 percent of that estimated by the state in 1933. The results of the Bureau's 1947 cost allocation are shown in the following table.

Cost Allocation and Estimated Repayment
Central Valley Project in 1947*

Function	Cost Allocated to Function	Estimated Repayment of Construction Cost	Per Cent of Reimbursable Cost Allocated to Function to Be Repaid
Navigation	$ 18,100,000(1)	0	
Flood Control	31,400,000(1)	0	
Irrigation	221,500,000(2)	$ 58,500,000	29
Municipal and Industrial	9,100,000	29,700,000	326
Power	104,100,000	227,800,000	219
Total	$384,200,000	$316,000,000	100

*From Document No. 146, House of Representatives, 80th Congress, First Session.

(1)Costs allocated to Navigation and Flood Control are nonreimbursable.

(2)Allocation to Irrigation includes $18,800,000 for costs incurred for increased canal capacity for future use, not a part of present project.

These results illustrate the very favorable terms for irrigation repayment. Irrigation under the initial Central Valley Project will meet only 29 percent of the construction costs incurred for its benefit. Such repayment would extend to the year 2009 without interest charges on the unpaid balance during the repayment period.

This repayment for costs charged to irrigation is to be secured from the difference in the rates per acre-foot to be charged for delivery from the main canals of $3.50 and $1.50 for Class I and Class II water, respectively, after deductions each year of the operation and maintenance costs. The repayment contracts are for periods of forty years. Such forty-year contracts at a fixed price for the period of contract protect the contracting units against the inflation that has occurred and may continue to occur during the contract period. At the time the rates for Class I and Class II water were set, they represented a reasonable estimate of the prices that the lands to be served could be expected to meet for water delivered at the main canals. Should costs of operation increase, the portion of these payments available to repay construction charges will be reduced below the amount estimated in the 1947 cost allocation.

The prices for water at the main canals do not include any costs for distribution to the lands of the contracting units. Costs for distribution, such as capital charges on the cost of the distribution system, operation and maintenance, and pumping, are additional to the payments to the Bureau for water.

In Part 2 of the Central Valley Project Documents, page 648 (85th Cong., 1st Sess., House Document No. 246), the 1958 estimate of the base project reimbursable cost is stated to be $413,668,000; the Trinity River Diversion and the Sacramento Canal Unit, $283,130,000; giving a total reimbursable

cost of $696,798,000 for the enlarged project. In addition, a total cost of $60,467,000 would be nonreimbursable for navigation, flood control, fish and wild live, and recreation. These results were prepared in 1957.

The allocation and probable repayment of the reimbursable costs for different project services for these 1957 estimated costs were as follows:

Function	Construction Cost		Interest and Earned Surplus	Percent of Allocated Cost to Be Repaid
	Cost Allocation	Probable Repayment		
Irrigation	$384,605,000	$279,160,300		73
Fish and Wild Life	2,737,000	2,496,300		91
Commercial Power	292,037,000	397,565,000	$242,735,800	136
Municipal and Industrial Service	17,419,000	17,576,400	21,556,600	124
Total	$696,798,000	$696,798,000	$264,292,400	100

These estimates are based on a repayment period extending to 2013 A.D. At that time the total reimbursable investment would be repaid. Power would have met interest charges on its allocated cost of $128,877,900 and would also have provided an earned surplus of $113,857,900 which will be used to meet deficits on functions, mainly irrigation, which would not fully meet their allocated costs. Municipal and industrial service would repay their allocated construction cost and would have returned interest on their unamortized investment.

In the present enlarged authorized Central Valley Project, the irrigation service to the areas included in the original project will be less than one-half of the total area to be served. For the total irrigation service, the total estimated revenues for the repayment period would be $510,000,000, with operating costs of $231,000,000. These operating costs are also estimated at present price levels.

To January 1, 1959, the Central Valley Project had had a gross revenue of $147,000,000 and a net revenue of $82,000,000. The net revenue had been credited to repayment of construction costs. The project investment at this date was $589,000,000, of which 93 percent is expected to be reimbursable; the repayment in the first twenty-two years of the project's history had been 14 percent of the cost to that date. This period includes the time required for the construction of the major works prior to their operation.

Reclamation Act Policies

The undertaking of the Central Valley Project by the federal government under the terms of the reclamation law provided a source of funds adequate for the completion of the project. It also brought into the project many policies and conditions that differed from those that had been anticipated under a state project.

The original reclamation law was passed by Congress in 1902, primarily to provide a means for the irrigation of public lands in the arid western states which would permit their settlement and use. The earlier projects were largely for such public lands. Later, areas of public land suitable for irriga-

tion became scarce and the activities of the Bureau of Reclamation were directed largely to the construction of irrigation systems for privately owned lands. The original projects were also based on providing a full water supply for the lands to be served. It was soon found that there were many areas having canals which lacked a complete water supply so that much of the work of the Bureau was directed toward providing supplemental water supplies for lands already under irrigation.

The original reclamation law was designed to meet the conditions on public lands and reflected the previous public-land policies. The size of farm a settler could secure was limited to the homestead area of 160 acres. Where privately owned lands were served, their owners were limited to securing water for not to exceed 160 acres. For the early projects providing a full water supply to arid lands of nominal initial value without water, these were sound policies. For projects supplying only supplemental water to lands already developed where the established agricultural economy had already created high land values, it was generally recognized that these limitations on area were neither suitable nor required. Congress itself has recognized this condition on some projects and exempted them from the acreage limitations by specific statutes. The Bureau of Reclamation had recognized the ineffectiveness of such provisions on other projects and had not forced the limitations.

On some early projects, land speculation had been detrimental to the project development. To meet such conditions, Congress, in 1926, amplified the land limitation provisions by passing the so-called anti-speculation amendment to the reclamation law. This retained the limitation of 160 acres for which an owner could secure water and added the requirement that, not only must the excess land be sold in order to secure water for the retained 160 acres, but the sale of the excess lands must be at prices fixed by the Secretary of the Interior. Such sale prices were to be based on the value of the land without a project water supply in order that the lands could be placed in the ownership of settlers at prices which would not include capitalization of the values resulting from the project benefits.

When the Central Valley Project was taken over by the federal government through the Bureau of Reclamation, the project became subject to all of the policies and procedures that controlled the operations of the Bureau. This was not fully realized by the people in the project area at the time the Bureau began its work, as the then activity of the federal government was regarded as a form of unemployment relief. Even the state continued to assume to direct policies and approve plans for the work of the Bureau during the first years of federal activity. Later, when appropriations were made by Congress for the project, as a part of the Bureau's general appropriations, it came to be recognized that the project had passed from state to federal control and that it was subject to all of the provisions of the reclamation law.

The provisions of the reclamation law were amended by Congress in 1939. This act defined separate terms for the repayment of costs chargeable to power or municipal use where they were a part of the project services. Alternate types of repayment for the costs of construction chargeable to irrigation were also provided. These changes applied to the Central Valley Project; their application to the conditions in the project has been the subject of wide differences in interpretation of the meaning of the law as well as the choice that should be made between the different repayment terms.

The areas to be served by the Central Valley Project represent one of the most highly developed agricultural economies in the United States. Many claim it is the most highly developed diversified crop area of its size in this

country. All of this development prior to 1935 had been the result of the initiative of its population without federal guidance or control. Those who have produced such an economy have naturally resisted efforts to use the delivery of a supplemental water supply as the basis for attempting to change the existing agricultural pattern. Those responsible for past results considered they were better judges of the needs and proper policies for this area than federal appointees lacking similar experience.

Efforts to secure legislation exempting the Central Valley Project from the acreage limitations were resisted by the then Bureau staff and those influenced by its "information service." Many hearings were held and voluminous testimony, much of it irrelevant, was taken. Out of this mass of conflicting claims a few factual points were developed. The Bureau admitted that at best only a "technical compliance" with the acreage limitation provisions could be secured, as the owner of excess lands could not be prevented from pumping water for his excess area from the mingled natural and project ground waters under his excess lands. Eventually, the interests of both the government and the landowners will require that this project perform the functions which it was built to serve. Any item, such as an acreage limitation, that may delay or prevent such a result will have to give way to this major criterion.

The policies relating to the disposal of the surplus project power have also been subject to much controversy. An average of about 13 percent of the total output of firm power will be used for project purposes, mainly for pumping from the Delta into the Delta-Mendota Canal. For this use of power by the project, an operating charge of two and one-half mills per kilowatt hour has been used in the project accounting. The sale of the surplus power is the largest source of expected revenue from which project costs will be repaid. In the fiscal year 1956 the total power production from Bureau plants was nearly three billion kilowatt hours. About two and one-half billion kilowatt hours of commercial power output were sold at a total revenue of $9,862,000, equivalent to an average rate of 3.64 mills per kilowatt hour. About one-half of the power sold was purchased by the Pacific Gas & Electric Company, one-third by the Sacramento Municipal Utility District, and the remainder by twenty-four other customers.

Project power was sold to the Pacific Gas & Electric Company under short-term arrangements until 1951. The Reclamation Act makes public agencies seeking to purchase Bureau power preference customers in its sale. From 1951 to 1957 the Bureau had made over twenty contracts with such preference customers. The largest of such users is the Sacramento Municipal Utility District. Power in excess of that used by the preference customers is sold to the Pacific Gas & Electric Company. The projected financing schedules of the project are based on the sale of firm commercial energy at 4.5 mills per kilowatt hour after 1966 and nonfirm energy at 2.5 mills.

Sale of power by the Bureau is made on a combined demand and energy charge rate giving an average rate of 4.5 mills for a load factor of about 63 percent.

Salt-Water Repulsion

California has two types of problems relating to salt-water intrusion. One is the intrusion of saline surface water into the Sacramento—San Joaquin Delta. The other is the intrusion of sea water into the ground water adjacent to the ocean. Both have their origin in the depletion of the original water supplies which has resulted from the use of formerly tributary flow.

The prevention of inflow of tidal water into the Delta has been a continuing source of differences of opinion for over thirty years. Many investigations

U.S. Bureau of Reclamation photograph

Delta-Mendota Canal of the Central Valley Project. This canal, 120 miles long, conveys Sacramento River water to the San Joaquin Valley.

U.S. Bureau of Reclamation photograph

Delta Cross-Channel of Central Valley Project

have been made. Most of the arguments have been concerned with whether some form of bay barrier at various locations could be built which would prevent inland movement of salt water.

The preponderance of the results to date supports the conclusion that such barriers can be designed and built within the standards of present engineering but that, under the limitations of other factors, they would not be effective in protecting the Delta. Any such bay barrier must be able to let the surplus inflow to the Delta escape to the Bay. Locks for navigation will be required and salt water will move through the barrier in the operations of the locks. A barrier cannot provide material storage of fresh water, as the height to which the levees in the Delta can be built is limited by their foundation conditions. Any barrier below Mare Island will need to provide for use by the Navy without interference with its repair facilities there. A bay barrier within a major part of the tidal prism behind the Golden Gate will change the scouring conditions there and affect navigable depths and channels used for entrance to the Bay.

Considering all of these conditions, it has been the conclusion of both the federal and the state departments concerned that salt-water intrusion into the Delta could be controlled most practically by the release of stored water during periods of low flow in amounts which would prevent intrusion of salt water of over 1,000 parts per million of chloride past Antioch. The early investigations indicated that this could be done with an outflow of about 3,500 second-feet at Antioch. Such a release has less costs under present conditions that that required for a barrier and more assurance of the results it may accomplish. The requirements for maintaining the quality of water in the Delta under existing operating conditions are still under investigation.

There are still some remaining points of uncertainty regarding how a salt-water barrier may function. The U.S. Army Engineers also have problems regarding the navigability of the Bay, particularly relating to the movement of sediment reaching the Bay from natural erosion and the continuing downstream transportation of debris from past hydraulic mining. To meet its needs, the Army Engineers have constructed a model of the Bay area which is being operated to reproduce the tidal and other conditions in the Bay and to determine the effect of changes in different factors. This model will also be operated to reproduce the effects that would result from different types and locations of bay barriers. When these results become available, more conclusive answers may have been found to some of the present differences in opinion regarding the effectiveness of a bay barrier. In the meantime, plans for operations in the Delta and for conveying water from the Sacramento Valley across the Delta to be pumped to the San Joaquin Valley can proceed on the basis of present results.

Drainage

Irrigation usually results in a need for drainage to remove part of the water used. Where canal seepage and percolation from the irrigated lands reach the underlying ground water in strata from which pumping may be practiced, a direct drainage system may not be needed. All natural waters contain some soluble salts and unless some drainage from the area occurs, such salts remain and in time may result in soil injury. For permanent irrigation a salt balance should be secured under which as much salt leaves the area in its concentrated drainage as enters it in its water supply.

Drainage has usually been left to local agencies in California. The state plans include drainage only where the extent of construction is beyond what local areas can provide. This is consistent with the plans for delivery of

water wholesale from the state aqueduct system. Only wholesale outlets for drainage are planned by the state.

The only drainage authorized to date for state construction is a drainage channel extending nearly the length of the San Joaquin Valley to remove waste waters and to maintain a salt balance in the areas now served and to be served in the Valley. This drainage canal will provide an outlet to the closed Tulare Lake Basin which now receives all surplus and drain water from use on its tributary area. This inflow is now consumed in the area of the former Tulare Lake.

The Reclamation Bureau

When liberal amounts of federal relief funds were made available to the Bureau of Reclamation during the depression, the scale and character of its activities were materially changed. As the funds had been made available for unemployment relief, the emphasis was on the rapidity with which they could be spent rather than on the economy of the results that were secured. Standards of project feasibility were lowered.

For the first thirty years after 1902, the construction funds available for use under the reclamation act varied from five to ten million dollars per year, with a total in that period of about $200,000,000. Only a relatively small compact organization was needed for this scale of operations. This organization was composed of engineers and directed by engineers who had secured their experience by service with the Bureau of Reclamation. It is probable that no other similar federal agency had secured the economy in the construction of public works that was secured by the Reclamation Service, the predecessor of the present Bureau of Reclamation.

The earlier Bureau had operated on too limited a scale to attract those seeking to establish bureaucratic control of its operations. After 1932 the greater extent to which power development was being included in the Bureau projects provided an opportunity to secure greater control over project areas. These conditions resulted in the gradual replacement of the experienced engineers in the administrative positions of the Bureau by those interested in building up the Bureau to control the water and power resources of the projects. The political conditions in the 1930's and 1940's were favorable to such reversals in Bureau policies. These changes were beginning to have their effect when the Bureau started its Central Valley Project in 1935. Much of its directing personnel lacked essential training and experience in its work.

Since 1952 the conditions in the Central Valley Project have been materially improved. Direction of the project was returned to experienced personnel. Excessive public relations activities (propaganda) were curtailed. Some of the points of conflict resulting from the terms of the reclamation act remain but the relationships of the areas served and the Bureau staff have been materially improved.

As of today, any comprehensive plan for the water development of the Central Valley must take into account the established position there of the Bureau of Reclamation. Further development by projects too large for local areas to construct will be by the federal or the state governments or by some joint effort of both. Further federal projects can be readily integrated with the present federal Central Valley Project. State projects can be constructed and operated separately, except where the physical works of the two agencies may overlap. The best results for both federal and state service will be secured by cooperative planning and construction. There is work enough to be done to provide full fields of activity for both agencies. Methods for such cooperation are discussed in chapter XIII.

Multiple-Use Plans for Use of the Colorado River

The development of the Imperial Valley by means of its local project has been discussed in chapter VI. The municipal water supply for Los Angeles, up to the point at which the southern California coastal area had to seek an outside water supply in addition to the Owens River, has been described in chapter VII.

Both of these areas had to look to larger and more distant projects for the water supply needed for their further growth. The amounts of additional water needed in the Imperial Valley and in coastal southern California and the extent of the flood menace in the case of the Imperial Valley made it necessary to seek a project which would control the Colorado River to remove its damages and to provide the benefits which its water could supply. The resulting project is generally known as the Boulder Canyon Project. The principal structure in this project, the dam at Boulder Canyon, is now known, at last officially, as Hoover Dam. The lake created by Hoover Dam has been designated as Lake Mead. Hoover Dam has a height of 726 feet and a storage capacity of 32,000,000 acre-feet. This is the highest dam in the United States.

Commercial power production began in October 1936. In June 1943 the power capacity exceeded 1,000,000 kilowatts. This was the first time any single plant had reached this total. The ultimate capacity is now planned to be 1,332,300 kilowatts. The annual power output for the ultimate project is estimated to be about five billion kilowatt hours per year.

Reports on the engineering features of controlling the Colorado River began to be made by the U.S. Bureau of Reclamation about 1916 and continued until the plans crystallized in the program for a large reservoir at Boulder Canyon.

In the activities leading to the construction of the Boulder Canyon Project, the southern California interests took a leading part. Many new problems in engineering, financing, interstate relations, and public policy were involved. The eventual success achieved was the result of the persistent efforts of the areas affected.

Colorado River Compact

As the Colorado River drainage area includes parts of seven states, it was necessary to make a division of the available flow among these states before the project could proceed. This was accomplished by an interstate compact. Legislative authorizations for the negotiation of such a compact were secured and an agreement among the negotiators was reached in 1922.

The Colorado River compact divides the river into an upper basin (above Lee's Ferry) and a lower basin. The drainage area in Colorado, New Mexico, Utah, and Wyoming constitutes nearly all of the "upper division" and California, Arizona, and Nevada the "lower division," as these divisions are defined in the compact. In each ten-year period the upper states are to allow a total of 75,000,000 acre-feet to flow past Lee's Ferry. This is one-half of the total available dependable flow as estimated at the time the compact was made. The lower states may acquire rights to the use of an additional 1,000,000 acre-feet per year if this should be found to be available. Any water right for use in Mexico, that might be recognized in future treaties, was to be supplied, first, wholly from any surplus over the above 16,000,000 acre-feet and, if necessary, equally from the apportionment to the upper and lower divisions. The dominant purposes are defined to be domestic and agricultural use with use for navigation and power generation subservient thereto. Each state retains the regulation of the use of its portion of the flow within its area subject to the general requirements of the compact.

The compact was promptly ratified by all of the Colorado Basin states except Arizona. A part of Arizona's disagreement related to the classification of the waters of the Gila River. This river is a lower tributary from Arizona which Arizona claimed should not be counted as a part of the Colorado River flow which the compact undertook to divide.

This condition continued until 1928. Congress had not ratified the compact, as it is usual to delay such Congressional action until all states that are parties have accepted its terms.

The Boulder Canyon Project Act

It was generally conceded that the Boulder Canyon Project could be built only by the federal government. Even if California had been in a position to finance its construction, the location of the dam on the boundary of Arizona and Nevada would have given rise to many questions of state authority. Efforts to secure federal authorization began in 1922, with the introduction in Congress of the first Swing-Johnson bill. Increasing support was secured as similar bills were introduced in succeeding sessions of Congress. Opposition by Arizona delayed its enactment but passage was finally secured in 1928.

When Congress passed the Boulder Canyon Project Act in 1928, federal ratification of the compact was made conditional on its ratification by six of the seven Colorado River states, including California, and the acceptance by California of a limitation on its claims to an annual consumptive use of 4,400,000 acre-feet per year plus one-half of any surplus flow that might be available. The act also authorized the construction of the All-American Canal. Total costs of $165,000,000 were authorized. The project was defined as useful: first, for river navigation and flood control; second, for irrigation and domestic purposes, and the satisfaction of the then perfected rights in accordance with the terms of the compact; and, third, for power. This definition differs somewhat from that in the compact but does not represent a conflict, as it is the basis of operation of the project rather than the division of water among the states. It was considered necessary to place navigation as a first use in order to provide legal support for the use of federal funds for the project. Arizona brought suit to enjoin the construction of the Boulder Canyon Project in 1930. This case was dismissed by the United States Supreme Court, which held that the project represented a proper federal activity and expenditure.

As Arizona did not ratify the Colorado River compact in time for it to be effective in starting construction on Boulder Dam, it was necessary for California to meet the requirements of the act in limiting her claims on the waters of the river. This was done in 1931, on the basis of an agreement reached between the California projects which would use Colorado River water. The division consisted of: first, such water as may be required for 104,500 acres in Palo Verde Irrigation District; second, for 25,000 acres in the Yuma Project in California; third, lands to be served by the All-American Canal in Imperial and Coachella valleys and 16,000 acres in the lower Palo Verde Mesa, with a total limitation on these three priorities of 3,850,000 acre-feet per year of beneficial consumptive use; fourth, the Metropolitan Water District of Southern California of 550,000 acre-feet; fifth, the Metropolitan District for 550,000 acre-feet and the county of San Diego for 112,000 acre-feet; sixth, for the same parties under the third priority of 300,000 acre-feet; and, seventh, all remaining water for agricultural use within the Colorado River Basin in California. This allocation was approved by the parties, the State of California, and incorporated in the water contracts made by the government.

Finances

The Boulder Canyon Project Act provided for a Colorado River Dam Fund, to which advances were to be made from the federal treasury. These were to be repaid within fifty years with interest at 4 percent on deferred payments, including interest at this rate during construction. Of the cost, $25,000,000 was assigned to flood control on which 4 percent was to be charged until paid. Excess revenues were defined as net income in excess of that required to meet the payments on the amortization of other costs in fifty years. Only 62½ percent of the excess revenues was to be used to repay flood-control charges, the remainder being divided equally between Nevada and Arizona. This provision for these states was a substitute for taxes that might have been secured from a similar private project.

Construction was not to be undertaken until firm repayment contracts for power had been made providing revenues adequate to meet the terms of the project act. The applications for power exceeded the supply. The available supply was allocated so that, finally, the city of Los Angeles contracted for 37 percent, the Metropolitan Water District for 36 percent, and the Southern California Edison Company for 27 percent. Los Angeles included in its part the underwriting of about 4 percent allocated to other municipalities; the Southern California Edison Company similarly underwrote minor shares for two other power companies; and both the city and the Edison Company were subject to a reduction of 18 percent for an optional future use by Nevada and Arizona.

The estimates of the Secretary of the Interior, on which the approval of the power contracts was based, gave a total required income over the fifty-year repayment period of $206,983,997. The contracts would provide a total income of $327,866,350, of which only $209,834,634 was considered to be guaranteed, as Los Angeles had not voted on its power contract and it was not, as yet, binding on the city.

If this full revenue was realized, the excess over the required income would have been used to repay $45,981,303 principal and interest on flood control, $22,665,441 each to Nevada and Arizona, leaving a balance of $29,-570,168 for the Colorado River Basin Development Fund.

The Boulder Canyon Project Act also provided that its power output should be sold at a price to be determined by the "competitive conditions at distributing points or competitive centers." The only competitive center was the general power market of the coastal area of southern California, as this was the only market large enough to absorb the output to be made available. Studies were made of the cost of equivalent power delivered to the Los Angeles area generated from other available sources; from this was deducted the cost of generation at Boulder Dam and of transmission to this market. This resulted in a rate of 1.63 mills per kilowatt hour as the competitive value of the energy obtainable from "falling water" at Hoover Dam. This rate was used to determine the rate of payments to be made by the power contractors.

Under the terms of the Boulder Canyon Project Act, the federal government underwrote the cost of the project, but construction could not begin until the government had firm contracts assuring repayment of all costs with interest at a rate in excess of the rate at which the federal government was then borrowing funds. This is the only comparable federal project on which this basis of financing has been used; other similar projects have involved substantial federal subsidies.

Adjustment Act of 1940

The original Boulder Canyon Project Act also provided that the price of power could be readjusted at the end of the first fifteen years and every ten years thereafter. As the act provided that the price should be based on the competitive price of other power, this resulted in uncertainties regarding the future power income. While the rates specified in the contracts for the first fifteen years provided surplus revenues, there was no assurance that surplus income would be available for payments to Nevada, Arizona, and the Colorado River Basin Development Fund after the first fifteen years of operation.

The fifty-year repayment period began June 1, 1937, when the project was prepared to deliver 1,250,000,000 kilowatt hours per year. At this time, power costs from competitive sources were decreasing and the interest rate on funds borrowed by the federal government had declined to about 2.75 percent. The policy of building other similar projects with their costs largely donated by the federal government had been adopted during the depression years. A request for adjustment was filed in 1937. Lengthy negotiations between the states were required before agreement was reached on the terms of the Boulder Canyon Project Adjustment Act and its passage secured on July 19, 1940. The interest rate was reduced to 3 percent. The falling water rate of 1.63 mills per kilowatt hour was reduced to 1.163 mills. The repayment of the $25,000,000 for flood control was deferred beyond the fifty-year period. A definite annual payment of $300,000 each to Nevada and Arizona was provided, with $500,000 per year to the Colorado River Basin Development Fund in place of the conditional amounts provided for in the original act. Revisions in the power contracts embodying these changes were completed May 29, 1941, just within the deadline allowed by the Adjustment Act.

Colorado River Silt

Silt has been, and continues to be, a major problem on the Colorado River. It represents about 1 percent of the volume of flow equal to about 150,000 acre-feet per year. As the storage capacity at Hoover Dam is about twice the mean annual flow, with complete deposit of the silt about 200 years would be required to fill the reservoir. The major portion of this silt comes from a part of the drainage area having only limited agricultural usefulness, so that erosion control at its source does not appear to be feasible.

The time before Lake Mead may be filled with silt will be extended as other upstream reservoirs are built. Even when silting may impair its storage capacity, the same head and water supply will be available for power generation. Repayment of all costs will be completed before silting affects the project income.

Colorado River Treaty with Mexico

A settlement of the division of the waters of the Colorado River requires the definition of the amounts and conditions of the delivery of water to Mexico. Such an international agreement is as essential as a compact between the states agreeing to the division among themselves of the waters available for use within the United States. This was recognized by both countries. When the United States sought to negotiate a treaty with Mexico regarding the waters of the Rio Grande in 1924, Mexico requested the inclusion of the Colorado River in the same negotiations. This was done in 1927. The representatives of the two countries reported their agreement on the terms of such a treaty in February 1944. A protocol clarifying certain provisions was signed

on November 14, 1944. The United States Senate conducted hearings in 1945 and ratified the treaty with eleven statements of explanation or reservations on April 18, 1945. The treaty became effective on November 8, 1945, when the ratifications were exchanged in Washington.

The terms of the treaty relating to the Colorado River were extensively attacked by the water interests of southern California. Nevada supported California's position and the other five Colorado River Basin states supported the treaty. The controversy was bitter; several questions regarding the interpretation and applications of the treaty remain controversial. As present flow to Mexico exceeds treaty requirements, these questions will not affect river operations until increased use in the United States may require restrictions on diversions.

Under the terms of the treaty, Mexico is to receive 1,500,000 acre-feet per year of Colorado River water delivered at the boundary in accordance with a specified monthly schedule. California has claimed that this delivery is materially larger than the use in Mexico had been at any past time. To meet this delivery, the treaty provides for the construction of additional works that may be required to fulfill its terms. Davis Dam has been constructed for this purpose.

Metropolitan Water District of Southern California

By 1923 the need for additional water in the southern California coastal basin had become apparent. The supplies which Los Angeles had imported from Owens River, with the additional water obtainable from the Mono Basin, were approaching full use. Other coastal communities were approaching or had reached the limit of their available supplies. The Colorado River represented the only adequate source then available to this area.

The undertaking of this project is an example of foresight and courage by an area which recognized that its growth would be defined by the water supply it could provide for its population. Los Angeles had shown similar courage in undertaking its Owens Valley system. The Colorado River was farther distant, with extensive mountain ranges to be penetrated. The territory to be traversed was forbidding desert. The water to be secured carried large amounts of silt and had greater content of soluble salts than other local sources. Only a large-scale project could hope to be feasible. The investigations of this project proceeded concurrently with those for the Boulder Canyon Project.

The Metropolitan Water District of Southern California was organized under the metropolitan water district act enacted in 1927. This act provides for joint participation in such districts by public agencies having common needs. Each proposed constituent unit votes separately on its participation in the district and only those voting favorably are included. The organization of the district was completed in 1928 with eleven members.

Many routes for the aqueduct were investigated. The route selected requires a pumping lift of about 1,600 feet. To divert and pump the 1,500 second-feet planned will require the use of about 300,000 kilowatts of installed power capacity, with an annual power consumption of over two billion kilowatt hours. The main aqueduct is 266 miles long, with 93 miles of tunnel and 19 miles of pressure pipe. The estimated construction cost was $220,000,000 for the initial capacity. Bonds in this amount were voted in 1931. Financing was secured through the sale of bonds to the Reconstruction Finance Corporation.

The diversion for the Metropolitan Aqueduct is at Parker Dam, 155 miles below Hoover Dam and just below the mouth of Bill Williams River. The 75

feet of head made available by the dam is used to develop 120,000 kilowatts of power from the water passing the dam. The storage capacity was 716,000 acre-feet.

The diversion dam at Parker presented complications, as it is located where the Colorado River forms the boundary between Arizona and California. There was doubt regarding the status of a California district constructing works in Arizona. To meet this situation, a contract was made with the United States Bureau of Reclamation to construct Parker Dam with funds provided by the Metropolitan District. The dam is also used for a diversion in Arizona and the power to be made available by the dam was divided between the Bureau and the District. When construction was begun, the governor of Arizona proclaimed martial law in the area on the Arizona end of the dam and sent the Arizona National Guard to take possession of the dam site area in Arizona and prevent work there. Congress in 1935 specifically authorized the construction of the dam and approved the contracts with the District. Work then proceeded without further difficulty in regard to the legal rights to build the dam.

The maximum height of the dam is 384 feet; of this height, 235 feet are below the elevation of the river bed. The depth to suitable foundation material in this dam exceeds the height to which the dam raises the water in the river.

Construction of the aqueduct was completed in 1941 and the project placed on an operation basis. The cost of the initial construction to deliver 750 second-feet from the Colorado River and to soften 620 second-feet was $205,000,000. The fourteen constituent areas in 1942 had a population in excess of 2,000,000 and an assessed valuation of two billion dollars. By 1959 the District covered an area of 3,300 square miles, including eighty-five incorporated cities. It had a total assessed value of over twelve and one-half billion dollars and a population of over seven million.

In the earlier years of its operation the aqueduct supplied supplemental water to its included units. The amount of water used was relatively small at the start and increased as the population and demand grew. In 1945-46 nearly 50,000 acre-feet were sold by the district. This represented about 10 percent of the total water used by the constituent areas of the district and about 5 percent of the ultimate capacity of the aqueduct. Use in 1956 exceeded 400,000 acre-feet. Enlargement of the aqueduct to its full capacity is now being completed.

The district adopted the policy of approving the annexations of additional areas only where any such area agrees to pay to the district the back taxes it would have paid if it had been a member from the time of the district's organization. To reduce the immediate burden of such charges, payments have been extended over several years.

San Diego Aqueduct

As a part of the Boulder Canyon Project, San Diego secured recognition of a right to take 155 second-feet from the western end of the All-American Canal and to convey it to its area by pumps and tunnels through the intervening mountains. This supply was programmed for construction when more complete use of local sources would require provision of an additional outside supply. The rapid growth in water demand during World War II, for the increased naval and civilian population at San Diego, resulted in a need for an increased water supply more quickly than could be met by the construction of such an aqueduct. Arrangements were made for a connection with the aqueduct of the Metropolitan Water District of Southern California at the westerly end of the San Jacinto Tunnel and the construction of a pipeline to San Diego.

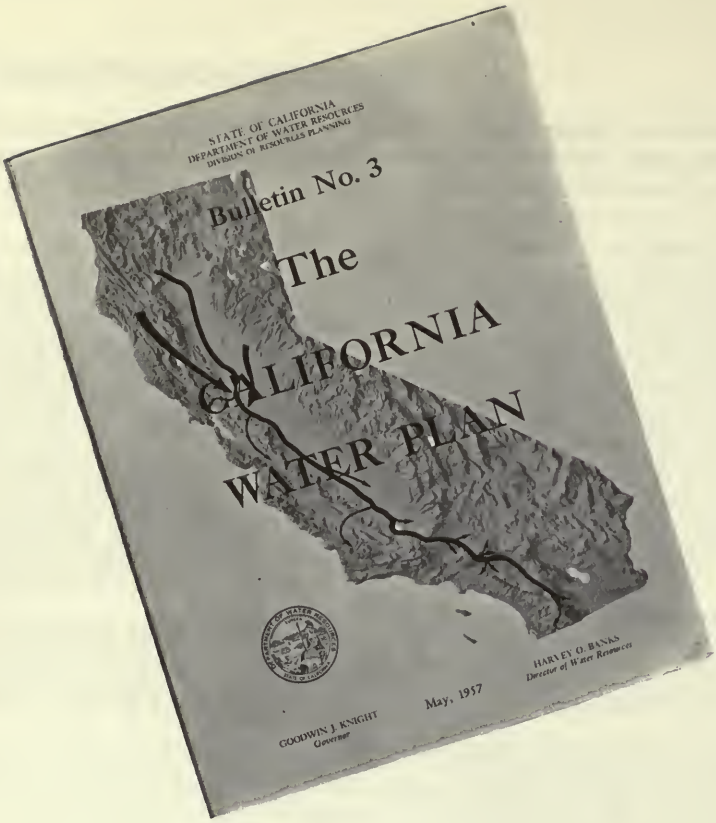
The San Diego County Water Authority was organized to include the areas in San Diego County participating in the use of this water. The area in this authority has been annexed to the Metropolitan District.

All-American Canal

The desirability of diverting and keeping the water used in the Imperial Valley entirely within the United States was recognized from the beginning of the irrigation of the Valley. The cost of such a canal route was greater than could be financed in the early years, so that the diversion canal followed a route in Mexico around the south end of the ridge of sand hills between the river and the Valley in the United States. The All-American Canal, entirely within the United States, was included as a part of the Boulder Canyon Project. To reduce the cuts through the Sand Ridge, the diversion dam is located five miles above the Laguna Dam of the Yuma Project. The capacity of the canal is 15,000 second-feet to the diversion of 2,000 second-feet for the Yuma Project. This is further reduced to 10,000 second-feet at Pilot Knob, where water is diverted for a power plant.

The Imperial Irrigation District has the rights to the power that can be developed along the All-American Canal. There are four principal drops having falls of 19 to 48 feet, with a total potential installed capacity of 63,000 kilowatts.

The Coachella Valley is an area, partly below sea level, in the vicinity of Indio. The locally available water supplies are limited. Irrigation from wells began in 1894, when the first artesian well was drilled. Depletion of the ground water resulted in the organization of the Coachella Valley County Water District in 1918, with an area of about 100,000 acres. Spreading works on the local streams were constructed to augment the ground-water supply. It was recognized that full use of the local supplies would be insufficient for the irrigation of more than a limited part of the district area. The outside source of supply needed has been secured by the construction of a branch from the All-American Canal extending around the northern side of the Salton Sea to the Coachella Valley.



CHAPTER XIII

Basin and Statewide Plans

Just as progress led from the local single-purpose project to the multiple-use development, the multiple-use projects have led to the planning of the future use of the water resources through comprehensive programs looking toward the complete use of the water supply of entire stream basins. Such comprehensive programs still represent plans on which progress is being made, with some individual units under construction.

Comprehensive planning attempts to foresee the ultimate use of the land and water resources of each basin. The resulting plans are necessarily limited by the human inability to see very far into the future or to forecast ultimate needs with certainty. These plans can be helpful if they are used to assist present decisions; they can be harmful if they are established as a pattern to which all present development must conform.

Principal items in any comprehensive water plan are inventories of the available water supply, the irrigable lands, and the potential hydroelectric power that can be developed. Forecasts of future population and industries to be served and their water demands are included. Other uses, such as flood control or navigation, may be important. Use for recreation, fish and wild

life are usually treated as by-products of the other main uses. Salt-water control is an added factor in some areas, such as the Sacramento—San Joaquin Delta.

During World War II, interest was developed in having a program of construction for water-resource development ready to meet the unemployment that many expected would follow the shutting down of war activities. General support had also been developed for coordinated use of water on a basin-wide basis and basin plans became a popular slogan. Comprehensive plans were prepared by the Bureau of Reclamation and the Army Engineers on several basins. Those completed during or soon after the war included the Missouri River, the Columbia River, the Colorado River, and the Central Valley. The last two of these are in or affect California.

Comprehensive basin plans are not new ideas in California. As previously described, in 1921 the Legislature directed the State Engineer to develop a plan for the "maximum conservation, control, storage, distribution, and application of all the waters of the State." This was done and the results presented in 1930 in Bulletin 25. Bulletin 25 proposed the immediate construction of the initial units in a comprehensive plan. These units have now been undertaken by the federal government as its Central Valley Project and its Boulder Canyon Project. The work on these initial units following 1930 resulted in less attention to ultimate plans by the state through World War II. However, the interest in developing each basin on a comprehensive scale continued; its accomplishment was merely deferred while the more urgent problems of current construction programs were met.

In 1947 the California Legislature directed the then State Water Resources Board to prepare a plan for the development and use of the water resources of the state. Work on this assignment resulted in the publication in 1957 of Bulletin 3, entitled The California Water Plan. Bulletin 3 had been preceded by Bulletin 1, Water Resources of California, in 1951 and Bulletin 2, Water Utilization and Requirements of California, in 1955. Bulletin 3 presented a description of water projects for all parts of the state. These projects included separate local developments and a general California aqueduct system which would convey water from areas of surplus to areas of deficiency. For some areas of the state this plan was a multipurpose program for full development of their basins. For much of the state the plan exceeded the scope of basin planning and represented a comprehensive over-all equalization of the water supply and demand on a statewide scale. The California aqueduct system would convey water from the Klamath River on the northern boundary of the state to the Mexican border in San Diego County. It represents the ultimate in state planning; any larger program would have to be interstate in its extent.

The accomplishments in recent years, in which record-breaking projects have become almost routine, have resulted in a public opinion that any water project can be built if there is sufficient need for it. While this opinion is complimentary to the engineering progress which has overcome almost all physical limitations on the size of structures and the distances of conveyance, it fails to include recognition that many things are now physically feasible which may not be financially profitable or sound. All comprehensive plans need to be checked in the bright light of public consideration to determine which portions are economically desirable before they are undertaken.

The reports on comprehensive basin or statewide plans have considered the over-all feasibility of the entire plan, based on its total cost and benefits. If the estimated total annual benefits exceeded the total annual costs, the plan has been considered to be feasible. Separate consideration of the feasibility

of individual units of the plan has not usually been included. Consequently, some units might be, and in some cases were, included for which the incremental costs have exceeded the incremental benefits. In determining feasibility, it has also been usual to include both direct and indirect benefits. The indirect benefits are those accruing to the public as a whole in addition to the benefits to the direct users of the project services.

In determining the feasibility of any comprehensive plan, it is also necessary to determine the collectible revenues which the project may produce. Benefits for which no salable products are obtained do not help to meet project costs. If such uncollectible benefits are used to reduce the costs allocated to income-producing services, a false picture of the project's ability to meet its costs will result. The costs allocated to nonincome-producing benefits are usually assigned to be met by some form of public subsidy. As pointed out in the report of the Assemby Water Committee of February 1, 1960, projects having a favorable benefit cost ratio may not be able to meet their costs from the payments obtainable from their vendible services. If a project is to repay its costs, its feasibility depends on the ability of the users of the vendible services to pay rates which meet such costs.

In the following discussion the comprehensive plans for the Central Valley and the Colorado River are first described, followed by planning for the entire state. In the state's work prior to 1947 the largest projects visualized were those conveying Sacramento Valley water to the San Joaquin Valley and the Colorado River to the southern California coastal plain. The investigations authorized in 1947 jumped the barrier of the Tehachapis and in 1951 proposed the Feather River Project to convey water from this stream to southern California. The state plan in Bulletin 3 also jumped the barrier between the Sacramento Valley and the north coast streams. The sequence of the discussion follows the sequence in the development of water-resources planning which has been used in California.

Comprehensive Plans for the Central Valley

Plans for the Central Valley, which can be considered as comprehensive, have been made by three agencies. These consist of the 1930 plan of the State Engineer, the 1945 plans of the Bureau of Reclamation, and the flood-control plan of the Corps of Engineers, U.S. Army. The latter plan was limited to units including or relating to flood control and navigation. Further plans for the Central Valley are included in the 1957 state plan in Bulletin 3.

As the comprehensive plans of the federal agencies were completed after 1944, they were subject to the procedure of the 1944 Flood Control Act and were submitted to the state for comment before they were presented to Congress. Such comments were prepared for the state by the State Engineer. These comments were of similar length to the reports on the plans.

The State's Plan in 1930

The 1930 plan of the state for the ultimate development of the Central Valley was based on conveying water from the Sacramento River drainage area to the upper San Joaquin Valley in a sufficient amount to meet its ultimate demands as such demands were then estimated. It was found that water could be made available for the full water requirements of both valleys. Only major canals were included in this plan, with local distribution systems left to be built by local agencies.

The estimated cost of twenty-four reservoirs, having a total storage capacity of nearly 18,000,000 acre-feet, was $492,000,000. At thirteen of these

reservoirs, power plants having a total installed capacity of 1,730,000 kilowatts would have an additional cost of $104,000,000. Major canals had an estimated cost of $88,000,000, giving a total cost of $684,000,000.

This plan would provide a water supply of 22,920,000 acre-feet for the irrigation of 8,000,000 acres. Unused water would remain in the Sacramento Valley, varying from 5,750,000 acre-feet in minimum years, such as 1924, to 10,000,000 acre-feet in average years and 15,000,000 acre-feet in excess years, such as 1927.

November 1945 Plan of U.S. Bureau of Reclamation

A report entitled Comprehensive Plan for Water Resources Development, Central Valley Basin, California was issued in November 1945 by the U.S. Bureau of Reclamation. It was a well-bound volume of nearly three hundred pages. The report found 2,400,000 acres needing supplemental water and about 3,000,000 acres of new land needing a full water supply. Of the total irrigable area in the Central Valley of 8,325,000 acres, about 3,540,000 acres were irrigated in 1943. With full development, it was estimated that the area actually using water in any year would be 6,580,000 acres having a water requirement of 16,600,000 acre-feet. Requirements for other uses resulted in an ultimate water demand of 20,000,000 acre-feet.

Based on 1940 prices, the construction proposed had a total estimated cost of $1,810,000,000. This estimated cost included the then authorized Central Valley Project which was a part of the comprehensive plan. It was estimated that $210,000,000 of the cost would be allocated to flood control and navigation and be nonreimbursable. Power would repay $830,000,000 of the cost and other uses the remainder of $770,000,000.

This plan proposed thirty-eight reservoirs, having a total capacity of about 30,000,000 acre-feet. The hydroelectric plants proposed had a total installed capacity of 1,700,000 kilowatts. With the 750,000 kilowatts of fuel power proposed to support this hydroelectric power, the average annual output was estimated to be 8.1 billion kilowatt hours. The total annual costs were estimated to be about $110,000,000 and the benefits $275,000,000.

The natural runoff of the Central Valley was found to have been an average of 33,000,000 acre-feet per year for the forty years 1903-1904 to 1942-43. For the seven years of minimum runoff from 1927-28 to 1933-34, the mean annual supply had been 18,400,000 acre-feet. This difference between such minimum periods and the long-time means illustrates the extent of variation which occurs and the difficulty of providing sufficient storage to enable such variations to be equalized. Even during such a seven-year critical period, it was estimated that the average annual outflow from the Central Valley basin with its then extent of development was 11,300,000 acre-feet. With 1,900,000 acre-feet of this outflow needed for salt-water repulsion in the Delta, the remaining 9,400,000 acre-feet was available for additional development.

The plan proposed in this report would reduce waste to the ocean to about 5 percent of the total water supply during the critical period. This would represent practically full use of the available water supply in such periods but would use only about two-thirds of the long-time average supply. The Bureau of Reclamation found that for this plan the estimated ultimate water demands of the Central Valley could be met during such a critical period. During periods of larger runoff substantial amounts of unused water would continue to reach the ocean.

The irrigation benefits to the nation as a whole, both direct to the users of water and indirect to others, were assumed to be measured by the gross value of the crops that would be grown with irrigation less the similar value

of the crops that could be grown without irrigation. This method gave an average annual irrigation benefit of about $15 per acre on the 2,000,000 acres to be provided with additional irrigation water and about $65 per acre on the 3,040,000 acres of new land to be irrigated.

Such use of gross crop income as a measure of the irrigation benefits was a development of the Bureau of Reclamation in its search for methods of evaluating project benefits. This method omits direct consideration of the costs of crop production. It assumes that the indirect benefits to others than the landowners will balance the cost of production. While this may occur under some conditions, it would be the result of coincidence rather than any direct relationship. The use of this method for deriving irrigation benefits in order to justify the costs of proposed projects aroused much discussion and is not now being used.

In accordance with the provisions of federal statutes, this comprehensive plan was submitted to the state for review. The State Engineer examined the plan proposed and reported his results and conclusions. He recommended completion of the presently authorized Central Valley Project and a group of other projects already authorized for flood control. Deferment of approval until further investigation had been made was recommended for another group of units; another group was recommended for authorization; an additional group was disapproved. The State Engineer found that the report did not satisfy the requirements of the statutes governing the submission of findings of engineering feasibility and concluded that each project in the plan should be reported upon individually as to its need and its engineering and economic feasibility. He also concluded that such reports on individual projects should be submitted to the state for comment before their submission to Congress for authorization. Other recommendations relating to the basis of repayment of reimbursable costs were also made. The state's report was a thorough review of the Bureau's plan, with sound conclusions relating to the program and policies which should govern project selection.

Plan of the Corps of Engineers, U.S. Army

In 1945 the U.S. Army Engineers made a comprehensive Flood Control Survey Report on Sacramento–San Joaquin Basin Streams. As the functions of the Army Engineers relate directly to navigation and flood control, their comprehensive report was limited to units which would provide these benefits. While comprehensive in these fields, the plan of the Army Engineers was not as fully comprehensive for the complete water development of the Central Valley as the similar report of the U.S. Bureau of Reclamation. The report of the Army Engineers did include consideration of other uses in flood-control units having other benefits.

At the time this comprehensive flood-control report was made in 1945, the 1916 flood-control plan in the Sacramento Valley had been practically completed and was in operation. The other more urgently needed flood-control projects in the Central Valley had been authorized, but little, if any, construction had been done on them. The 1945 Army Engineers' plan included the authorized projects and additional projects recommended for authorization. The total estimated cost for the projects in this plan was $438,000,000. The average ratio of benefits to costs was 1.27 to 1.0.

This plan was reviewed by the State Engineer and recommendations were made regarding its various features, based on the same standards that had been used in his similar review of the comprehensive plan of the Bureau of Reclamation.

Comprehensive Plans for Southern California

In 1930 the State Engineer included a discussion of the ultimate water needs of southern California in his report to the Legislature (Bulletin 25). This report did not include a complete plan for meeting such needs. The total water requirements for the full development of the south Pacific Coast basin were found to exceed the supplies available from local sources by an average of 1,800,000 acre-feet per year. It was estimated that the net habitable area of this basin was about 2,000,000 acres. It was concluded that outside supplies of 400,000 acre-feet per year from the Owens and the Mono basins and about 1,000,000 acre-feet from the Colorado River could be secured. This would leave some shortage in the supply required for ultimate development.

Report on Colorado River by U.S. Bureau of Reclamation

In March 1946 the Bureau of Reclamation issued a report entitled "The Colorado River. A National Menace Becomes a National Resource. A Comprehensive Report on the Development of the Water Resources of the Colorado River Basin for Irrigation, Power Production, and other Beneficial Use in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming." In the report, as in this title, lengthy wording replaced engineering facts to a large extent. This so-called comprehensive report did not present a comprehensive plan for the development of the Colorado River Basin. It undertook to describe various units which might become such a plan. The total units described had water requirements in excess of the available water supply, so that all of them could not be included in any comprehensive plan. The report did not attempt to make a selection between these units, nor did it include sufficient factual material to enable the report to be used as the basis for such a selection. This report represents an inventory of possible projects in the basin rather than a plan for their development.

In this report, 134 individual projects are described. These were all within the natural drainage basin of the Colorado River. Any projects in addition to those then existing or authorized to transport water from the Colorado River Basin to other basins were not included. There are such transmountain diversions both completed and under construction.

Of the lower basin projects, only one was wholly in California and one partly in California and partly in Arizona. These California projects were the Palo Verde Mesa, having an estimated cost for 1946 prices of $5,000,000, and the rectification and control of the river channel between California and Arizona, having an estimated cost of $8,000,000.

In the report prepared by the Bureau of Reclamation dated March 22, 1946, the cost estimates were based on costs as of January 1940. In the letter transmitting this report to the Secretary of the Interior dated June 6, 1946, the cost estimates were revised to current construction costs at that time. The total estimated costs of the 134 individual projects described, based on 1940 conditions, was $2,185,442,000; the similar estimate for 1946 conditions was $3,460,497,000, an increase of 58 percent. The 34 projects in the lower basin, principally for use in Arizona, had total estimated costs about one-third greater than the total estimated costs for the one hundred projects in the upper basin.

The relatively minor proportion of the projects described in this report which are located in California is the result of the extent to which California projects using Colorado River water had already been constructed. The All-American Canal and the initial capacity of the aqueduct of the Metropolitan Water District of southern California had been completed when this report

was prepared, although their use had not reached the water supplies to which they will be entitled under full development. While the projects described in this report are located in the other Colorado Basin states, they are of direct interest to California, as their development will have a material effect on the use of Colorado River water and the supply remaining for use in California.

The lands to be furnished with irrigation water were as follows:

	New Land Acres	Land Furnished Supplemental Water Acres	Total Acres
Upper Basin	1,230,810	504,170	1,734,980
Lower Basin	303,150	618,100	921,250
TOTAL	1,533,960	1,122,270	2,656,230
Area in California	16,000	0	16,000

The power development proposed had a total installed capacity of 3,600,400 kilowatts, of which about 55 percent would be in the lower basin. The estimated annual firm generation was 19.5 billion kilowatt hours.

For all of the projects described in this report, the annual costs were estimated to be $108,000,000 and the annual benefits $138,500,000, giving an overall benefit cost ratio of 1.3 to 1. These results apply to the cost conditions of January 1, 1940.

In the estimate based on 1946 costs, the ratio of average annual benefits to annual costs was stated to be approximately 1.00 to 1.00. Using the benefits as estimated in the March 1946 report with the 1946 costs, the ratio of benefits to cost would be less than unity. Any actual construction of any such a program of projects will be extended over a relatively long future period so that any present estimates of benefits and costs are necessarily subject to the uncertainties of future price conditions. The results in this report indicate that the feasibility of these projects, as a group, will depend on decreases in the costs of construction or increases in the value of the benefits. For 1946 conditions this group of projects as a whole did not meet usual feasibility standards.

The present and potential depletion of the water supply of the Colorado River Basin was estimated as follows:

	Estimated Average Annual Depletion in Acre-feet			
	Existing or Authorized Projects			
	Present Depletion	Possible Increase	Potential Projects	Total Ultimate Depletion
Upper Basin	2,199,800	556,000	6,380,700	9,136,500
Lower Basin	4,918,000	3,583,000	2,559,700	11,060,700
TOTAL	7,117,800	4,139,000	8,940,000	20,197,200
Area in California	2,680,000	2,946,000	176,000	5,802,000

The Colorado River compact of 1922 left the division of the waters allotted to the upper and the lower basins to be made by the states in each basin by later agreements. An Upper Colorado River Basin Compact was executed by the states concerned on October 11, 1948, and became effective on April 6,

1949, following action by Congress. This compact recognized a use of 50,000 acre-feet per year of upper Colorado River water in Arizona for its limited area in the upper basin. The remainder of the upper basin supply was divided 51.75 percent to Colorado, 11.25 percent to New Mexico, 23 percent to Utah, and 14 percent to Wyoming. This apportionment recognizes, but is not directly proportional to, the runoff each of these states contributes to the upper Colorado River.

The Upper Colorado River Storage Project

The Colorado River Storage Project was authorized in 1956, covering projects in the upper Colorado River basin. Four reservoirs and eleven participating projects were authorized for construction. Twenty-four so-called participating projects to be given priority in the completion of planning reports were named. This act created the Upper Colorado River Basin Fund to receive all federal appropriations and project revenues. Reimbursable costs are to be repaid within fifty years, except for two designated participating projects. Revenues credited to the basin fund are to be used to pay project operating costs and to meet the federal repayments. Net revenues in the Basin Fund are apportioned among the states to be used to repay the costs of participating projects in each state.

In addition to the nonreimbursable costs for flood control and fish and wild life, allocations of costs to recreation are to be nonreimbursable. Costs allocated to power and to municipal use are to be paid, including interest during construction, at an interest rate to be set by the Secretary of the Treasury each year equal to the average rate of interest paid by the United States on its long-time outstanding indebtedness in that year. Any revenues in the Basin Fund in excess of operation costs and repayment for power and municipal use are to be credited to the repayment of costs allocated to irrigation. The cost authorized in 1956 was $760,000,000.

A report entitled Financial and Economic Analysis, Colorado River Storage Project and Participating Projects was issued by the Bureau of Reclamation in December 1958. This report presents the results to its date and the estimated future cost allocations and repayments. The prime construction contracts on three of the four main reservoirs had been let and they were actively under construction. Construction on two participating projects began in fiscal year 1959 and three more were scheduled to start in 1963. Further investigations had resulted in findings that one of the authorized participating projects (Pine River Project extension) would not be able to pay its operation and maintenance costs and it was excluded from the scheduled program of development.

The remaining ten authorized participating projects had a total irrigable area of 346,000 acres, of which about two-thirds would be supplemental service to lands now irrigated. The four authorized reservoirs had a total capacity of 34,670,000 acre-feet, of which 28,040,000 acre-feet are in the Glen Canyon reservoir. A total installed power-plant capacity of 1,228,000 kilowatts is planned. The average annual increase in usable irrigation supply was 610,600 acre-feet and the increase in stream depletion 1,095,000 acre-feet. This increase in stream depletion includes 691,000 acre-feet of evaporation from the four reservoirs. The December 1958 estimate of the cost of the authorized project was $1,003,000,000; about two-thirds of this cost was for the storage units and transmission of power to market centers and one-third for the cost of the authorized participating units. Annual costs were estimated at $7,971,000, about 80 percent being for the cost of the reservoirs and power.

The thirty-two-year period, 1914-45, was used to determine the available

water supply. The average annual virgin flow at Lee Ferry for this period was estimated to be 15,640,000 acre-feet and the present annual man-made depletions in the upper basin to be 2,550,000 acre-feet. The virgin flow is the flow which would have occurred without man-made depletions. It was estimated that by the year 2062 the upper basin depletions would be increased to 6,191,000 acre-feet. It was expected that silting would reduce the initial active storage in the four authorized reservoirs of 26,853,000 to 22,443,000 acre-feet by 2062. About 5,590,000 acre-feet of additional silting was expected to occur in the dead storage capacity to be used to maintain minimum power heads.

All benefits resulting from the authorized project that could be evaluated in monetary terms were used to derive the benefit-cost ratio. The Bureau of Reclamation used a one-hundred-year period in deriving its benefit-cost ratio and, also, at the request of the Bureau of the Budget, derived the ratio for a fifty-year repayment period. The latter period represents the general repayment period; the one-hundred-year period was used to represent the useful life of the main construction items. For the one-hundred-year period the over-all benefit-cost ratio was 1.3 to 1 and for the fifty-year period the ratio was 1.1 to 1. For the one-hundred-year period the benefit-cost ratio for the individual participating projects varied from a maximum of 2.4 to 1 to a minimum of 1.0 to 1 for two units. For the fifty-year period three participating projects fell below a benefit-cost ratio of 1.0 to 1.

The repayment schedule, as computed in this report, shows that power revenues would repay all costs allocated to power with interest at 2-7/8 percent per year by 2010, would repay storage costs allocated to irrigation of $108,000,000 in the four following years, and would make available $891,000,000 additional by 2049 for use in the repayments of costs of participating projects. As the participating projects authorized in the 1956 act have a present estimated cost of $324,000,000, a substantial surplus is estimated to be available by 2049 to be applicable to repayment of costs of additional participating projects.

The Upper Colorado River Storage Project represents a recent illustration of the extent to which Congress has been willing to subsidize irrigation development with federal funds where power production is included in the project. Power is to be sold at the cost of the next available source. In this area this is considered to be the cost of generation of steam power of six mills per kilowatt hour for firm power and 2.5 mills for nonfirm energy. Revenue from power, in excess of its costs including interest, will be available to subsidize irrigation. For the participating projects authorized in 1956, the estimated reimbursable costs of $323,774,000 would be repaid, without interest—$41,098,000 by the water users and $282,676,000 from power revenues. On this basis the costs allocated to irrigation will be met, 13 percent by the water users and 87 percent from surplus power revenues. The irrigation repayments will, in addition, be without interest on their deferred payments; this interest waiver on the irrigation repayments, for present periods of repayment, is equivalent to an additional subsidy of about one-half of the principal to be paid. For the costs allocated to irrigation to be repaid from surplus power revenues, the interest waiver will extend to the time when costs allocated to power have been fully repaid and surplus power revenues have become available.

The 1956 Colorado River Storage Project is limited to units in the upper basin. Future federal work in California under comprehensive plans for the Colorado River will be limited in extent as the use of California's share of the water supply of the river is now fully provided for by existing systems

or will be provided for by locally constructed works. California has an interest in developments in the upper Colorado River basin in relation to their effect in reducing the flow at Hoover Dam available for power generation and eventually in their possible effect on the required deliveries to the lower basin to meet the terms of the Colorado River compact. The results in the December 1958 report of the Bureau of Reclamation forecast a total stream depletion in the upper basin by 2062 of 6,191,000 acre-feet per year. This would leave sufficient mean annual flow to meet the compact delivery requirement of 75,000,000 acre-feet for each ten-year period until after 2062.

Present Colorado River Litigation

In 1952 Arizona brought suit against California for a determination of the division of the Colorado River supply to be available to the lower basin compact. As previously discussed, the upper basin states had made such a division by an upper basin compact. Agreement on a lower basin compact had not been reached. This suit being between the states in their sovereign capacities was initiated in the U.S. Supreme Court. In accordance with usual practice, it was assigned to a Special Master to hear testimony and recommend a decree. Nevada and the United States intervened in the case and New Mexico and Utah were made parties to the extent of their lower basin interests. The hearings were completed in August 1958 after about 25,000 pages of testimony and 4,000 exhibits. There 121 days of hearing, with over six million words in the transcript. The master's finding may be submitted in 1960, with the final decision following after argument before the Supreme Court.

Statewide Water Plans

The preceding discussion of the comprehensive plans that had been prepared prior to 1946 furnishes the background on which the state's work on an over-all state water plan was undertaken in 1947. The results were published in 1957 as Bulletin 3, entitled The California Water Plan.

Bulletin 3 describes a plan by which the water supply of the state, wherever it may occur, can be regulated and conveyed to any area in the state where there may be a potential demand for its use. The requirements of all land found to be physically irrigable and of the projected ultimate population wherever it may be located would be met.

The results in Bulletin 1, relating to the water resources of the state, and in Bulletin 2, relating to the land resources and their water requirements, have been discussed in chapter II. As the surplus water is in the northern part of the state and as areas of deficiency extend to the southern border, any really comprehensive water plan for California is necessarily statewide in its scope.

In its investigations on which its water plan is based, the state found existing and potential areas of intensive water service in California of about 23,600,000 acres. Of this total area, 20,000,000 acres were classified as suitable for irrigation and 3,600,000 acres for urban, suburban, and industrial types of use. To supply the needs of these areas, it was estimated 51,100,000 acre-feet per year would be required. Of this total use, 41,100,000 acre-feet would be needed for irrigation, 8,300,000 for urban, suburban, and industrial use, and 1,700,000 acre-feet for miscellaneous purposes. These estimated total ultimate requirements represent about 70 percent of the estimated total mean annual water supply of the state. These results have been the basis which supports the conclusion, stated in Bulletin 3, that the waters originating in California, together with the rights of California in and to the

waters of the Colorado River, are adequate in quantity and quality to satisfy all water requirements of the state after it has reached full development, if the waters are properly controlled, conserved, protected, and distributed. This conclusion is correct insofar as the quantitative relationship of supply and demand are involved. It is also correct in regard to the ability to design and construct works for bringing the water to the areas needing its use. It lacks completeness in indicating the portions of the plan which may be financially feasible.

The plan proposed in Bulletin 3 would provide 11,600,000 acre-feet per year for export from the north coastal area. It would also provide 10,300,000 acre-feet per year to be exported from the Sacramento River basin besides providing some 7,000,000 acre-feet per year for local uses there. The export supply from the north coastal area and the Sacramento River basin would be available for use as follows:

	Acre-feet
San Francisco Bay Area	2,200,000
Central Coastal Area	1,200,000
South Coastal Area	2,900,000
San Joaquin–Tulare Lake Basin	8,600,000
Lahontan Area	4,800,000
Colorado Desert Area	1,400,000
Salinity Control in Sacramento–San Joaquin Delta	900,000
TOTAL	22,000,000

The limitations of the plan proposed in Bulletin 3 were recognized by its authors. The following separate quotations from the report express some of these limitations.

"The very magnitude of the task involved in formulation of The California Water Plan was such that detailed surveys and studies, and economic and financial analyses, could not be undertaken in this initial phase of investigation. At this stage of its development, therefore, the Plan must be regarded as no more than a broad and flexible pattern into which future definite projects may be integrated in an orderly fashion. As additional data and experience are gained, as technology advances, and as future conditions change in manners that cannot be foreseen today, The California Water Plan will be substantially altered and improved. However, the basic concept of the Plan as a master plan to meet the ultimate requirements for water at some unspecified but distant time in the future, when the land and other resources of California have essentially reached a state of complete development, will remain unchanged."

"The California Water Plan is neither an inflexible regulation nor a construction proposal as it is presented herein. It does not purport to include all possible water development projects in the State. Rather, it serves to demonstrate that the full satisfaction of ultimate water requirements in all parts of the State is physically possible of accomplishment. Therefore, the omission of any project from description in this bulletin does not preclude its future integration into the Plan."

"Although The California Water Plan is capable of accomplishment from an engineering standpoint, its component features have widely variant relationships to present concepts of economic and financial feasibility. It is realized that certain of the works would be extremely costly under present value criteria. Such works are for the indefinite future, and their need may never materialize. However, the economics of the distant future cannot be

foreseen, and the planning effort is deemed necessary at this time in order that provision may be made for such developments, if and when they become needed and justified."

Power would be both developed and used by this plan. The new hydroelectric plants would have a total installed power capacity of about 7,800,000 kilowatts and a seasonal energy production of about 34 billion kilowatt-hours. To operate the plan would require pumping installations of about 12,300,000 kilowatts capacity, using about 49 billion kilowatt-hours per season. The overall power consumption of the plan would exceed its production by about 45 percent.

Some cost estimates are included in Bulletin 3. These serve a useful purpose as illustrations of relative costs to be expected. Except for the Feather River Project, these cost estimates are not based on sufficiently complete investigations to be used to determine feasibility of individual parts of the plan. As the plan, if it should be constructed, will be built over a relatively long future period, any cost estimates prepared at this time cannot foresee the conditions at the time when deferred portions of the plan may be built.

The cost of all features of this plan were estimated to involve a total capital expenditure of some $11,800,000,000, based on 1955 price levels and economic conditions. This total cost consisted of $2,800,000,000 for developments to meet local water requirements and $9,000,000,000 for the cost of the California aqueduct system.

The totals which have been given for different items in the plan proposed in Bulletin 3 include the conveyance and use of water in the high desert areas of southern California. High pumping lifts and costly conduits would be required to deliver water to these areas. The effect of deleting service to these high desert lands is discussed in Bulletin 3. Such deletion would reduce the total annual water requirement of the plan by 5,800,000 acre-feet and the estimated total cost by $4,400,000,000. The estimated total power requirements of the plan would be reduced from 49 billion kilowatt-hours to about 19 billion kilowatt-hours. Service of these lands would require both large construction and operating costs which exceed the value of the use of water in these areas or the price which could be paid under any present standards of feasibility. There can be general agreement with the conclusion stated in Bulletin 3 that "Development of the demand for this water service cannot be foreseen at the present time."

The State Water Plan presented in Bulletin 3 was submitted to the Legislature with the recommendation that:

"The California Water Plan be accepted by the Legislature as the general and coordinated master plan for the progressive and comprehensive future development of the water resources of California by all parties, subject to: (a) more detailed investigation and study of component features of the Plan to determine their need, engineering feasibility, economic justification, financial feasibility, and recommended priority construction; and, (b) continuing review, modification, and improvement of the Plan in the light of changing conditions, advances in technology, additional data and future experience."

"Projects to achieve the objectives of the California Water Plan to be constructed as their need, engineering feasibility, economic justification and financial feasibility are demonstrated by further investigation."

Legislative Action on Plan

The 1958 Legislature did not act on the state water plan proposed in Bulletin 3. The 1959 Legislature designated the plan in Bulletins 1, 2, and 3 to be known as "The California Water Plan." The Department of Water Re-

sources was directed to make amendments, supplements, and additions to the plan which are to become effective when reported to the Legislature. The Legislature may also adopt similar amendments. The plan was accepted as the guide for the orderly and coordinated control of the water resources of the state. It was declared that this acceptance "does not constitute approval of specific projects or routes of transfer of water for construction by the state or for financial assistance by the State without further legislative action, nor shall this declaration be construed as a prohibition of the development of the water resources of the State by any entity."

Action of 1959 Legislature on State Projects

The 1959 Legislature provided continuing funds for water development and passed the California Water Resources Development Bond Act, submitting an issue of $1,750,000,000 general obligation bonds for similar use to a vote in November 1960. These actions occupied much of the time of this Legislature session.

Previous Legislatures had authorized the Feather River Project and provided funds for acquiring rights of way and for constructing the relocated highway and railroad around the Oroville Reservoir site. There was strong administration support for undertaking the state's water program on a more active and more definite financial basis.

The principal purpose of the Bond Act (Senate Bill 1106, Chapter 1762) is to authorize $1,750,000,000 of general obligation state bonds for use in the construction of water projects by the state. Such bonds, together with the other funds made available by direct legislative action, are estimated to be sufficient to complete the construction of the state's Feather River Project and the other local projects provided for in the act.

This act creates a California Water Resources Development Finance Committee, consisting of the Governor, the State Treasurer, the State Controller, Director of Finance, and Director of Water Resources. This committee will have control of the issuance of bonds and the allocation of funds received from their sale.

Senate Bill 1106, as passed by the 1959 Legislature, is both a general bill creating an organization which could be used to construct the entire state water plan when funds for such construction may be made available and a particular statute relating to providing funds for and defining the state's Feather River Project. As the construction of this project is the main purpose of Senate Bill 1106, the further discussion of this act and other 1959 water legislation is essentially a discussion of the Feather River Project.

The State's Feather River Project

Senate Bill 1106 defines the "State Water Facilities" which are to be made available by this act. While additional facilities may be authorized by the Legislature as a part of the California Water Plan, the facilities named in this act comprise the Feather River Project as it had been proposed in the state's 1951 and 1955 reports and previously authorized by the Legislature. Senate Bill 1106 also provides that other facilities which the Department of Water Resources may deem to be necessary and desirable to meet local needs and to augment the supplies of water in the Sacramento–San Joaquin Delta may be included with the facilities named in the act.

The "State Water Facilities" defined in Senate Bill 1106 include the following:

1. Oroville dam and five upper Feather River reservoirs,

2. an aqueduct system from the Delta to serve areas from Solano to San Diego counties.
3. works in the Sacramento–San Joaquin Delta,
4. drainage in the San Joaquin Valley,
5. generation and transmission of electrical energy,
6. local facilities,
7. necessary relocations and rights of way for items 1 to 5.

A schedule of estimated costs, proposed date of completion, and amounts of water to be made available was prepared by the Department of Water Resources during the 1959 legislative session. This schedule included the following estimates.

The estimated state cost of the Oroville Reservoir was $390,000,000. This is exclusive of the expected federal contribution of about $70,000,000 for flood control. The Oroville Reservoir will provide a mean annual supply of 970,000 acre-feet per year to meet the ultimate demands in the Oroville service area and will augment the Delta supply for diversion in the aqueduct system. It was scheduled to be completed in 1968.

The five authorized reservoirs on the upper Feather River had a total estimated cost of $5,980,000. Two of these would make available 27,000 acre-feet per year for irrigation and three would be used mainly for recreation. These reservoirs were scheduled to be completed in 1962.

The aqueduct system included a North Bay Aqueduct having an estimated cost of $28,000,000, a completion date of 1965, and a mean annual delivery of 197,000 acre-feet; a South Bay Aqueduct having an estimated cost of $35,000,000, a completion date of 1962, and a mean annual delivery of 152,000 acre-feet; a Pacheco Pass tunnel having an estimated cost of $15,000,000, a completion date of 1965, and a mean annual delivery of 37,000 acre-feet; and a San Joaquin Valley–southern California aqueduct having an eastern and a western branch in southern California and a coastal branch ending in Santa Barbara County, with a total estimated cost of $1,076,000,000, completion dates from 1965 to 1971, and a mean annual delivery of 1,280,000 acre-feet to areas in the San Joaquin Valley, 1,346,000 acre-feet south of the Tehachapi Mountains, and 266,000 acre-feet from the coastal branch. In addition, the aqueduct system included the San Luis Reservoir to be built in cooperation with the federal government, with an estimated state cost of $190,000,000.

The works in the Delta included levees and other construction having an estimated cost of $53,000,000. Drainage in the San Joaquin Valley was estimated to cost $24,000,000. The facilities for the generation of electrical energy were those at Oroville Dam, having an estimated cost of $94,000,000 which was included in the estimated cost of the dam.

The local facilities specified in the act were not designated in location or individual cost. The act provides that $130,000,000 of the bonds are to be available exclusively for local projects as such projects are defined in other acts of the 1959 Legislature.

The power output obtainable from the Oroville Dam, if sold at market value, is expected to meet the costs of the reservoir, so that this item in the project can be self-supporting from power. The aqueduct system from the Delta has an estimated cost of $1,421,000,000 and would make available an estimated mean annual total water supply of 3,278,000 acre-feet. These results represent an average construction cost of $435 per acre-foot of mean annual yield. This supply is in addition to the supply to be made available for use in the Feather River service area.

It was estimated that the full use of the water to be made available by the project in the amounts previously stated would be reached in 1985. Use in

the earlier years of the project operation would increase to these totals as the demand developed. The act specifies that the aqueduct is to have a capacity of not less than 10,000 second-feet as far as the initial offstream storage, which will be the San Luis Reservoir.

Except for the five reservoirs on the upper Feather River and the $130,000,000 of bond funds to be spent on local projects, the proposed use of the bond issue approved by the 1959 Legislature represents the Feather River Project as proposed by the State Engineer in his 1951 and 1955 reports. Changes in aqueduct location, estimated costs, and water deliveries have been made, resulting from the continued investigations, but the scope and purpose of the project is essentially the same as that in the earlier reports.

The 1955 report of the state was based on selling water from the aqueducts (without costs for local distribution) at prices varying from $7 to $9 per acre-foot in the San Joaquin Valley, $17.50 to $22.50 per acre-foot in the San Francisco Bay area, and $25 to $45 per acre-foot in southern California. These prices included consideration of both the costs of service to the different areas and the ability of municipal and industrial uses to pay higher prices than irrigation.

The 1955 report included a schedule based on a construction program and an estimate of the rate at which the water use in the earlier years of project operation would increase until the project capacity was reached. The resulting total income during the period of bond repayment, based on such use and the above prices, would exceed the project costs. The capital expenditures will have to be incurred before deliveries of water can be made and full use of the water supply made available will not occur in the earlier years of project operation. To meet deficits in the earlier years of operation, the 1955 reports proposed that the state should advance funds to be repaid during the later portions of the bond repayment period when the income from the expected volume of sales would produce surplus revenues.

In the state's 1955 report it was estimated that a total accumulated deficit in revenues of about $500,000,000 would occur in the first thirty-eight years of the project. From the thirty-ninth to the fifty-seventh years the revenues were expected to exceed the costs by an amount sufficient to repay the principal of this deficit. The state proposed a forty-year bond issue with maturities beginning in the tenth year.

In its review of the state's 1955 report on the Feather River Project, the Bechtel Corporation reached similar conclusions regarding the need for financing the project with general obligation bonds. The Bechtel report proposed using fifty-year bonds with smaller rates of maturity in the earlier years. Interest during construction would be paid from bond funds. The resulting contribution from the state in the early years of the project operation under the conditions used in the Bechtel report would be about $250,000,000.

The state's 1955 report was based on an interest rate on the general obligation bonds of the state of 2.5 percent and the Bechtel report was based on 2.7 percent. Both of these rates are lower than the $3\frac{1}{2}$ to 4 percent now estimated to be applicable to such bonds. An increase in the interest rate on the bonds used to finance the project would materially affect the amounts of state contribution, as estimated in these 1955 reports, needed to meet deficits in income during the early years of project operation.

The proposed method of meeting bond costs in the early years of the project operation proposed by the state in its 1955 report applied the method used in financing the Metropolitan Water District of Southern California to the Feather River Project on a statewide scale. In the Metropolitan District early bond charges and operation deficits were met by taxes on the included agencies in the district.

The bonds to be issued under Senate Bill 1106, if approved by the voters, will be general obligations of the state. An appropriation is made in the bill, for each year, of the amount required to meet any part of the principal and interest on the bonds which may not be available from project revenues. The bonds may have maturities of not to exceed fifty years. All revenues from the sale of water and power or other sources are to be used, first, to meet operation and maintenance costs of the project, second, to meet bond payments, and, third, any additional revenues may be used to construct additional works.

The Department of Water Resources will be the constructing and operating agency of the state. It is directed to make contracts for the sale of water and power. Such contracts are not to be impaired by subsequent acts of the Legislature during the life of any bonds issued under the act. However, there are no statutory standards established directly in Senate Bill 1106 regarding the basis on which prices for water and power in such contracts are to be determined and no requirement that such contracts shall be secured prior to the incurrence of construction costs for the delivery of water.

Senate Bill 1106 contains a provision making the State Water Resources Development System subject to the terms of the Central Valley Project Act. The Central Valley Project Act (Section 11455) requires that contracts be entered into which will provide revenues at all times to meet all project costs including bond charges. The Central Valley Project Act, as a whole, is based on the use of revenue bonds and creates no state liability for any bonds that might have been issued. Senate Bill 1106 is based on general obligation bonds and creates a full state liability for any bond charges which project revenues may not be able to meet.

The Central Valley Project Act (Code Section 11560) directs the Department to construct the project when, in its judgment, funds available from appropriations, contributions, and revenues, including contracts for the sale of project services, are sufficient to meet all costs incurred prior to construction, all costs of construction, operation and maintenance, repairs and replacements, and all payments on bond principal and interest as they become due.

The preceding discussion relates to the statutory provisions in Senate Bill 1106 applicable to the repayment of funds secured from the sale of general obligation bonds of the state. They are not made applicable to the repayment of appropriations from the general fund or from investment funds transferred to the water fund.

In addition to Senate Bill 1106 providing for a bond issue for state water projects to be voted on at the November 1960 election, the 1959 Legislature created the California Water Fund and transferred the Investment Fund to the Water Fund. The Investment Fund contained the accumulated income from past receipts from oil royalties on state lands. There was about $170,000,000 in the Investment Fund at the time of this transfer. The mean annual future receipts to this fund may be $20,000,000. All of the Investment Fund was made available for use as the Water Fund. All future receipts for use in water development, such as direct appropriations, proceeds of bond sales and net water project revenues are to be placed in the Water Fund. Assets in the fund are to be expended only on appropriation by the Legislature. Project revenues needed to meet operation costs and debt service are to be used for these purposes and only the net revenues are to be deposited in the fund.

The 1959 Legislature revised previous legislation relating to state financial assistance to local projects by establishing a Local Projects Assistance Fund of $15,000,000, to be obtained by a transfer from the California Water Fund. The Department of Water Resources was authorized to make loans up

to $4,000,000 to public agencies which substantially conform to the California Water Plan, are engineeringly feasible, economically justified, and where there is "a reasonable assurance that the public agency can repay it." Grants up to $300,000 may be made for costs properly allocated to the enhancement of fish and wild life, and for reservoir costs for providing recreational functions of statewide interest. Where it may be in the public interest to build local projects to greater capacity than may be needed for local use, the state may finance the costs in excess of those needed for such local uses. Interest on loans from the Assistance Fund is to be paid at the rate being paid by the state on its general obligation bonds. This act also provides that the Local Projects Assistance Fund shall be abolished and its resources transferred to the California Water Fund if Senate Bill 1106 is approved by the people at an election.

Senate Bill 1106 provides that funds from other sources in the Water Fund shall be used in lieu of bond funds. However, it also provides that to the extent the Water Fund is decreased by such in-lieu use for the construction of state water facilities, an equal amount of the proceeds of the sale of bonds shall be expended for additional facilities as the Department of Water Resources determines to be necessary or desirable to meet local needs and to augment the water supply of the Delta by works in the drainage areas of the Sacramento Valley and north coastal streams.

The works of the aqueduct system which are to be built with the proposed bond funds are defined. There is no similar list or definition of local projects. In Bulletin 3, plans for local development are described and cost estimates stated. However, there are no findings regarding the feasibility of such local projects.

Water Supply for Feather River Project

The estimated water supply to be made available by the Feather River Project for export from the Delta under present conditions of use in the Sacramento Valley is about 3,300,000 acre-feet per year. This would be secured from the regulation of Feather River by the Oroville Reservoir and the surplus flows in the Delta stored in the San Luis Reservoir.

In its 1955 report on the Feather River Project, the state derived the surplus flows into Suisun Bay in excess of the flow estimated to be necessary to repel saline waters from the Delta for each year from 1921 to 1951 (Table 12). These results varied from 31,400,000 acre-feet in 1938 to practically zero in 1924, and less than 1,000,000 acre-feet in 1929, 1931, 1934, and 1939. The annual mean for the thirty-one-year period was 9,650,000 acre-feet. The mean for the seven years, 1929 to 1935, was 1,900,000 acre-feet.

In Bulletin 2, also published in 1955, the state found the mean annual runoff of the Sacramento River basin to be 22,390,000 acre-feet, its safe yield to be 19,040,000 acre-feet, its own ultimate water requirement to be 7,720,000 acre-feet, leaving a safe yield surplus of 11,320,000 acre-feet. With 2,093,000 acre-feet of this surplus needed for the operation of works in the Sacramento-San Joaquin Delta and for transmission losses, a mean annual exportable surplus of about 9,200,000 acre-feet would be available.

Not all of the exportable surplus runoff of the Sacramento River basin is available for export by the state's Feather River Project. The federal Central Valley Project now uses a part of this surplus for diversion into its Delta-Mendota Canal and plans to use additional amounts for its other present and planned units of this project. Increased use of water in the Sacramento Valley will reduce the surplus flow now reaching the Delta. For the Central Valley Project as now built and as proposed, the Bureau of Recla-

mation estimates that its total annual demand will be 8,300,000 acre-feet. This consists generally of about 5,100,000 acre-feet to be used from tributaries to the Delta before it reaches the Delta, 1,900,000 acre-feet to be exported by the Delta-Mendota Canal for the present Central Valley Project, and 1,300,000 acre-feet expected to be diverted above the Delta by the proposed canal along the east side of the San Joaquin Valley now under preliminary investigation. There will also be an annual demand on this Delta surplus flow of 1,250,000 acre-feet for the San Luis Unit. This demand is additional to that previously stated for the state and federal projects and would be added to the water requirements for whichever agency may supply the San Luis area.

These total demands on the surplus flows of the Delta from the Sacramento Valley exceed the estimated amounts of such surplus flows. Additional input to the Delta will be needed before the ultimate demands of these projects can be supplied. The state has recognized this requirement. Section 12938 of Senate Bill 1106 provides for additional works in the watersheds of the Sacramento River and north coastal streams to augment the supplies of water in the Sacramento—San Joaquin Delta, although funds for these works are not provided in the bond issue except as there may be other sources of income to the California Water Fund.

The present surplus supply in the Delta will be subject to reduction as the use of water in its tributary drainage areas increases. Under the present preferences to the areas of origin, such uses can be made without recourse by those exporting water under earlier priorities. The state has estimated that the 4,000,000 acre-feet of annual supply which could now be made available by the Feather River Project will be reduced to 3,000,000 acre-feet by 1990. The cost of replacing this reduction under present area-of-origin statutes will fall on the exporters from the Delta.

In a publication entitled Water, Today and Tomorrow, issued by the state in 1959, a diagram showing "Staging of Major Development" illustrates the development needed to meet the increasing demands that would be met by export from the Delta. The San Luis Reservoir, supplied from the unregulated Delta surplus, could meet these expected demands to 1975, when the additional supply from the Feather River Project and Delta Diversion Improvements would be needed. It is estimated that an additional supply would be required from some other source by 1982. This diagram shows the Middle Fork of Eel River development completed in 1982 and the first unit of its Trinity River development in 1985.

The present projects of the federal government and the plans of both the federal government and the state have demands for export from the Delta or reduction of its inflow which exceed the past surplus outflow. The different units of both agencies have varying and intermingled priorities of application to appropriate water for their use. In the pending hearings on the applications of the U.S. Bureau of Reclamation to appropriate water for its Central Valley Project, the state has filed protests against some federal applications and the federal agency has similarly protested some state applications. Efforts are being made to adjust any conflicts between the state and the Bureau of Reclamation regarding the division of the available unappropriated water when it may be insufficient for the needs of both. Negotiations are in progress seeking to reach a basis of agreement on a division of the available supply.

Statement of Administrative Policy

In January 1960 a general statement of the policies under which it was proposed to operate the project was issued by the Governor. These policies were

made explicit in a related statement issued by the Director of the Department of Water Resources.

It was proposed that power produced by the project should be sold at its market value. Costs allocated to power would be included in the allocation of costs for water service and any net revenues from power would be used to reduce the water rates. It was estimated that the power credit in the earlier years of the project might amount to nearly $2 per acre-foot of the project water supply. Later, with increased project pumping, the cost of power used by the project would exceed the earnings from power production but any power earnings would be similarly credited.

A common rate for all water sold in and above the Delta would be used, based on the costs for works in and north of the Delta. All water exported from the Delta would be subject to this Delta rate. Rates for water and power and other reimbursable items would be established so as to return to the state all costs of project operation, maintenance and replacement, and all principal and interest on funds secured from the sale of state bonds or other sources. Contracts for water from the project would be made for fifty-year terms, with options for their renewal. Rates for water would be subject to revision to meet changes in costs. The total contracts for sale of water would not exceed the project capacity, estimated to be 4,000,000 acre-feet per year of dependable water supply. Shortages would be prorated.

Construction of any transportation facility financed wholly or in part through the sale of bonds, would not be started until water service contracts had been executed which would insure recovery of at least 75 percent of the cost of such facility. As a general policy, contracts will be executed with public agencies having taxing powers which can be used to meet payments to the state.

The contract obligations to be required prior to construction would be based on the fixed costs of the transportation facility. This would consist of the repayment of principal and interest on the construction costs plus a minimum charge for operation and maintenance. This minimum operation charge would be mainly the depreciation which would occur if the facility should not be operated. If this requirement is met, the state would have enforceable contracts, prior to construction, sufficient to meet 75 percent of the costs even if the contracting agencies took no water on completion of the construction. If no additional contracts were secured after construction began, there would be a 25 percent deficit on the capital costs which the state would have to meet.

In an attempt to meet the opposition to providing water from a state project to lands in large ownership, it was proposed that all lands should meet all costs for their service and that any power credits would be applied only to lands held in ownerships of less than 160 acres for an individual and 320 acres for community property. If the full cost of the service furnished by the state is repaid by the users of water, there is no subsidy to be used to create "unjust enrichment" of the landowner. The proposed denial of credits for power earnings to large landowners has little relationship to the real issues involved in excess lands.

The Director's statement proposed a two-part charge for water. This consisted of a fixed amount per year sufficient to meet the capital charges for interest and principal on the project costs together with a minimum operation and maintenance cost and a rate per acre-foot of water used sufficient to meet the costs of operation, maintenance and replacement. The fixed annual charges would become due on completion of the service facilities; the annual charge for water used would be payable each year on the amount of water

used. This basis is similar to that proposed in the 1955 reports, except that the areas to be served would be required to meet the capital charges from the beginning instead of any deficits in income being met by the state.

In the January 1960 proposed basis of rates, the price for water in each area of service would be based on the cost of service to that area. A minimum charge to all users of $3.50 per acre-foot would be made for all uses in and above the Delta and for all water exported from the Delta. For separate aqueducts diverting from the Delta, the cost of water would be based on the costs under each aqueduct. For the main aqueduct to southern California, costs would be allocated to each area of service on the basis of the cost of the portions of the aqueduct used in its service.

Estimated operation and maintenance costs were tabulated in this statement for fourteen separate project service areas. These, including the $3.50 per acre-foot Delta water rate, varied from $7.50 per acre-foot for the north Bay aqueduct to $35.50 per acre-foot for the main area to be served from the east branch of the aqueduct to southern California.

In a statement furnished to the Legislature during the 1959 session, the Department listed the amounts of water to be made available to the different areas of service. These totalled 4,275,000 acre-feet per year. Using these deliveries with the rates per acre-foot for the operation and maintenance charges in the January 1960 statement indicates a total expected annual revenue from this source, when the water supply is fully used, of about $70,000,000. This is an average of about $16 per acre-foot; this result includes the Delta rate of $3.50 per acre-foot.

The estimated annual capital cost repayment was expressed in terms of the total amount necessary to repay with interest the portion of the capital cost of the aqueduct system allocated to each service area, based on a fifty-year payout period. The capital cost component also includes a minimum maintenance and replacement charge which would be paid irrespective of the amount of water used. The annual total of the capital cost components allocated to the fourteen service areas was $68,620,000. For the total water supply to be made available by the project, this capital cost component also represents an average annual charge equivalent to about $16 per acre-foot. For separate areas, the capital cost component varies from $7 to over $50 per acre-foot of the supply allotted to each area. The higher capital costs per acre-foot would occur in the areas having large separable construction costs and limited amounts of use.

These results represent an estimated total annual cost of the project, when its supply of over 4,000,000 acre-feet per year is fully used, of about $138,-500,000, equivalent to an average total cost of about $32 per acre-foot of the total project supply. Excluding use above the Delta, the export supply of about 3,300,000 acre-feet per year would have an average total charge of about $41 per acre-foot when the entire supply is fully used. Until fully used, the average payment for both operation and maintenance and for capital charges would exceed this cost for full use. In a year when all areas might use one-half of the total export supply, the payments for water would average $16 per acre-foot for operation and maintenance and $32 per acre-foot for principal payments, a total of $48 per acre-foot.

The preceding costs do not include charges for importing additional water to the Delta to maintain the present supply when increased use in the Sacramento basin may reduce the present Delta surplus. As previously discussed, the state estimates that such additional supplies may need to be made available by 1982. The cost of such additional supplies from north coastal streams or by other storage in the Sacramento basin will exceed materially the pres-

ent proposed Delta rate of $3.50 per acre-foot. In considering the rates and terms at which water will be sold, in order that project costs may be fully repaid by the users of its services, account should be taken of the time when such additional works may be needed, their estimated costs, and their effect on the repayment terms proposed to meet the costs of the presently proposed bond issue.

The Governor's statement in January 1960 included an announcement that he did not intend to call a special session of the Legislature prior to the election in November 1960 on the issuance of bonds for project construction. If no special session is called, the January 1960 statements of the Governor and the Director of the Department of Water Resources, or their later revisions, will represent the only assurance available to the voters regarding the financial program which it is intended to use in handling the bond funds, if the bond election should carry.

These January 1960 statements are based on statutes only to the extent that Senate Bill 1106 makes the provisions of the Central Valley Project Act applicable to repayment of bond funds. They are not policy statutes of the state which can be amended or repealed only after consideration by and action of the Legislature. These January 1960 statements represent administrative declarations of the present incumbents which may be revised by themselves or by their successors. Without legislative action, the policies which they state will be binding on the state only to the extent that they may be made a part of executed contracts with agencies purchasing project services.

The January 1960 statements of policy that repayment contracts covering at least 75 percent of the fixed charges will be required before construction of a project unit will be started, represents a recognition that present statutory provisions do not require repayment agreements prior to construction. There are no present statutory provisions defining any percentage of repayment prior to construction; any repayment requirements resulting from the reference to the Water Project Authority Act, if binding on Senate Bill 1106, would require the full repayment specified in the Water Project Authority Act.

Contracts for sale of project waters, based on the standards defined in its statement, are being sought by the Department of Water Resources. The progress that may have been made in securing such contracts at the time of the election on the bonds will furnish the best available basis on which the voters can reach a conclusion on the adherence to the principles in these statements by the state and the willingness and intention of the prospective users to purchase water from the project under these terms. Unless the prospective users of the project supply are able and willing to purchase water at the prices required to meet its costs, the voters of the state may well decide not to approve the issuance of state bonds for the construction of the project. There will be time between January and November 1960 to test the progress of contract negotiations based on these principles relating to repayment.

CHAPTER XIV

Today and the Future

The preceding chapters have discussed the extent of California's water resources and the accomplishments to date in their development. The record of the progress that California has made in water matters is interesting to Californians, but its principal value will be its use as a guide to what can be and should be accomplished during the coming years. Certainly the Californians of today have a marked advantage over the state's pioneers. The land and water resources have been measured and the raw materials available for water projects are known. Past experience has, or should have, defined the economic, physical, and political limitations applicable to water development.

In looking backward, time has furnished a perspective of the relative importance of the various problems that have arisen and have been met. In looking ahead, matters close at hand may appear to be larger than their real importance may justify. Whatever may happen, California will not stand still and solutions of some kind will be found to present conflicts and uncertainties regarding how desired results can best be secured. Any local differences which may have been retarding progress will, of necessity, have to give way to the greater needs of the whole state. Policies will have to be selected and fol-

lowed which will enable California to supply the requirements of its increasing population. In reaching this result, some matters which appear to be of large present concern may be forgotten in the histories prepared a hundred years from now.

The conditions in 1960 for the subject matter of the preceding chapters are reviewed in the following discussion. From these results, and the past experience of the state, conclusions are reached regarding the policies that appear to be essential if the state is to undertake its own water development on a statewide scale.

Conditions in 1960

The effects of man's operations in California are apparent throughout the state. While Californians take a justifiable pride in these accomplishments, the state still lacks much of being a finished product insofar as the use of its water resources is concerned. It is difficult for the present Californians to picture the state as it existed prior to statehood; it is equally difficult to picture the state as it may appear in another hundred years. The changes yet to be made may be as extensive as those already accomplished. Coming generations will not have grounds to complain that they have received a finished product with all the water resources in use and with no problems left for them to solve or projects for them to build.

Extent of Water Resources

There has been no essential change in the extent of the water resources of California during the last hundred years. Knowledge of such resources has increased and records of their extent have been secured so that fact has largely replaced surmise in this field. There is no basis for concluding, however, that the water supply of the state is changing toward either more moist or more arid conditions at a rate which will affect present programs. We should now know the range of variation to be expected both for single years and for series of years. This is the result of more extensive records rather than any change in climate. We will still have an occasional greater flood or drought than any previously recorded, but the frequency of such occurrences is reduced as the period of record is extended.

The records of the precipitation and runoff of the last hundred years are the best basis on which to estimate the probable supply of the next hundred years. It is not to be expected that the pattern of the last century will repeat itself in detail, but the extremes and the average should be closely similar to those of the past. We should not hope for an increase in the available stream flow and we should not fear its reduction.

As discussed in chapter II, the mean annual water supply available for development and use in California is about 77,000,000 acre-feet. Of this, perhaps one-fourth is now used and consumed and the remaining three-fourths still escapes. We have utilized the more readily available and easily secured parts of the total supply. Additional use will involve increasing difficulties and costs. The state now estimates that the ultimate water requirements will equal about two-thirds of the total water supply. On this basis, the future increase in use will be about one and one-half times the extent of the present use. We have now reached less than one-half of our expected ultimate use.

These statements relate to the state as a whole. The results presented in chapter II show that a major part of the water supply of the state originates in areas having limited present use or prospective demand. Nearly all of the dependable water supplies of southern California and the southern San Joa-

quin Valley are now fully utilized, but there are still large amounts of unused runoff in the Sacramento Valley and the north coastal areas.

The stream flow represents the original source of usable water. Some reuse of municipal water supplies by the reclamation of sewage can increase the usefulness of the original supply. The largest amounts of sewage occur in the metropolitan areas of southern California, where the cost of alternate imported supplies will be relatively high. As discussed in chapter II, extensive use of reclaimed sewage will require both a relatively high degree of treatment and a change in public thinking regarding its use. Delay in securing additional imported water could force providing such treatment and overcoming present prejudices.

For present planning, reclamation of sea water does not appear to be competitive with the cost of imported water. The supply of sea water is unlimited and it is a potential source if present investigational work is successful in reducing the cost of desalting so that the resulting product may be competitive with alternate sources. The prospect that such reductions in the cost of desalting sea water may be obtainable in time to meet the increasing needs in southern California does not justify delaying other plans for securing additional water for this area.

Weather modification, represented by artificial increase in the precipitation, does not appear to offer a promise of changing the present over-all water supply of the state to an extent that will affect present water planning on a statewide scale.

It is concluded that California will have to rely on its present stream flow as the source of its water supply for its increasing use of water. Should other sources, such as reclaimed sewage or desalted sea water, come into use, any plans for additional use of present stream-flow sources can be adjusted to the then results. However, the urgency of providing water for the impending needs is too great for the state to defer its present water program in the hope that such other sources will become available and competitive.

Water Rights and Water Laws

Much progress has been made in defining the principles governing the title to the use of water in California. After much turmoil and strife, a generally definite and stable basis was found for such titles. The constitutional amendment of 1928 established a requirement of reasonableness applicable to all uses of water. This has removed the major grounds for conflict between riparian owners and appropriators from surface streams. The system of title to the use of percolating ground water, established by the courts in 1903, has enabled California to make extensive use of this type of water supply.

It is not probable that major changes will be made in the present principles governing rights to the use of water which have been acquired and are now vested. Extensive values have been established under present principles which would be subject to large losses if material changes should be made. Regulation under the police power to secure reasonableness of use will be enforced, but there is no need for changing the present ownerships and control of acquired water rights. The state, however, has a wider range of discretion in the basis on which it will grant title to the remaining unappropriated water of the state.

Until recently, rights to the use of unappropriated water were open to acquirement under a definite process. Compliance with this process entitled the applicant to a permit to appropriate the water for which he could show a reasonable need. Priority of application was a substantial factor in securing such permits and diligence in construction and use was essential to the retention of the permit and securing a license.

The Legislature has included provisions in the present water code exempting state applications from diligence and establishing preferences for areas of origin. The provisions authorizing the state agency administering the acquirement of rights to consider the public interest in granting permits are being used by the present Water Rights Board to an increasing extent as the controlling basis for their actions. These provisions differ substantially from those previously in use and have created confusion and uncertainty in this field. Comments on these matters have been included in chapter III. The present situation can be summarized as follows.

Diligence

Any process for acquiring rights in the use of unappropriated water should be in the public interest, fair to all types of applicants, and uniform in its enforcement. These requirements are not met when any special class of applicants receives preferential treatment. The past standards of diligence were established as a reasonable requirement for progress and to prevent holding title without use. The state cannot consistently enforce more strict standards of diligence on others than it enforces on itself. The long periods without active progress that have been established for state applications by the Legislature represent means of holding water from use that would not be permitted to others. The unavoidable result is a general weakening of the standard of diligence for all applicants.

Preferences to Areas of Origin

The statutes creating preferences for areas of origin have not been before the courts for definition of the extent to which they may be applicable. The state's attorney general has found them to be valid acts of the Legislature. They have not been construed in relation to the 1928 constitutional amendment requiring all uses of water to be reasonable.

The long efforts that were required to find a means by which a lower riparian owner could be prevented from stopping use by an upper appropriator, even when the riparian use was unreasonable, have been discussed in chapter III. The area-of-origin acts attempt to create in lands, in the counties of origin, or in the drainage areas of origin, rights similar to those of riparian lands adjacent to streams, although the lands given this special status may not be riparian to the supply and for the counties of origin may not even be within its drainage area.

The issues relating to these area-of-origin preferences do not involve any water for which rights to use have already been acquired, either in the areas of origin or elsewhere. Such legislative acts can only affect acquirement of title to the remaining unappropriated water. The areas of origin in the Sierras were the location of the earliest extensive uses of water in California and have had the same opportunity to use their local water supplies that other areas have had for the past one hundred years. Rights have been acquired for downstream use to practically all of the late summer flow of these streams and the exercise of an area-of-origin preference will require storage of flood flows.

Some of these area-of-origin preference statutes are self-conflicting between the county of origin and the drainage area of origin. Portions of Lassen County in the Great Basin would have a preference under the county-of-origin statute over lower lands in the Feather River drainage area which might claim a preference to its water under the drainage-area statute.

Regardless of sentimental desires or statutory provisions relating to special preferences to areas of origin, the expected growth of California will require the effective use of its available water supply to meet the demands of greatest public benefit at the locations where such demands may occur. Such demands will not arise in the upper counties of major drainage areas. A preference to such areas will not result in large consumptive uses of water unless excessive costs for projects in these areas are met from some outside source.

The valley lands in the Sacramento Valley have similar economic conditions relating to the value of the crops which can be grown to those generally applicable to the San Joaquin Valley. When demands for additional irrigation develop in the Sacramento Valley for its valley areas, the economy of the state will be benefited by their use of water. The cost of placing Sacramento drainage area runoff on lands in the Sacramento Valley is and will be less than the cost of conveying the same amounts of water to similar lands in the southern San Joaquin Valley. As the Sacramento drainage area has runoff in excess of its ultimate needs, water will be available for the irrigation of its own valley lands.

Any statutory preferences to areas of origin are restricted to uses which can meet the constitutional requirements relating to reasonable use and methods of use. Reasonableness of use should include reasonableness of costs in relation to the results secured. Projects within areas of origin for which reservations are attempted should be required to meet economic standards justifying their construction. Unlimited reservations for extents of use which may not be feasible now or in the foreseeable future will only delay or prevent more beneficial uses in other areas. Areas of origin do not have inherent rights to the water originating in their areas, except in conformance with the general standards of reasonableness of use which are applicable to all uses.

Public Interest

While the amendment to the Water Commission Act stating that, in granting permits, consideration should be given to the public interest has been in effect for many years, it has not been dominant until recently, particularly since the establishment of the State Water Rights Board in 1956. This Board undertook to clear its backlog of deferred hearings which had accumulated under the former Division of Water Resources. In some of the decisions of the Board, the conclusions regarding the public interest have been given greater weight than other matters, such as the priority of the applications.

The public interest is an intangible item on which individual opinions may, and frequently do, vary. The present use of water now going to waste may represent a greater public interest than some other possible use which may not be made until some indefinite future time.

In the earlier cases involving discretionary actions on permits, by the agency administering the Water Commission Act, the courts restricted the action of the agency to passing on the correctness of the form of the application and the availability of unappropriated water. The present practice of the Board makes the issuance of a permit dependent on the Board's conclusion regarding how the remaining unappropriated water may be best used to serve the public interest. Prospective appropriators need a more specific basis on which they can rely during the period of preliminary investigation and expense of their proposed projects.

Until appeals from the decisions of the Water Rights Board have been decided by the courts, there will continue to be confusion and uncertainty re-

garding acquirement of rights in the remaining unappropriated waters of the state. Unless the state is going to be responsible for all future water development, there is need for a consistent and orderly process by which other forms of organization can proceed with the projects adapted to local construction. If the state adopts a policy that development by the state is the only form of construction which is in the public interest, there will be a state monopoly on all of the remaining unappropriated water.

Pollution

Until recently, water pollution has been of relatively less importance in California than in many other states. Pollution of surface streams had been limited, as the major cities were on the coast. These conditions have changed. Discharge of sewage or industrial wastes where they may reach and pollute underground waters has become a matter of serious concern in some areas. The pollution resulting from some types of industrial waste drew attention to the need for means for its correction and control. The State Water Pollution Control Board was created in 1949 and was given jurisdiction to control pollution of the waters of the state. The need for such control is increasing as the state's population increases.

Different Uses of Water

Progress in the use of water for different purposes has varied. For some uses, such as hydraulic mining or navigation, the peak of use may have been passed. Other types of use are much less complete. The more complex projects involving multiple uses of water are just getting well under way. Comment can best be made by discussing each use separately.

Hydraulic Mining

While much ground for hydraulic mining remains, the problems of disposal of the mining debris and the narrow margins between costs and returns for much of the materials to be handled makes doubtful the extensive revival of such mining. Hydraulic mining served a useful purpose in the earlier stages of California's history, but it is now overshadowed by several other uses of water. While eventually means may be found to secure the values in the remaining placer deposits, even the revival of the former extent of such mining would now be of much less relative importance to the state than it was in the earlier years.

Navigation

Navigation of inland waters is now a less important method of transportation than in the early years of the state. The principal remaining use of inland navigation is to Stockton and Sacramento. Any further development of navigation will be as a by-product to other uses of water. Navigation has, and will, give way to other uses where it conflicts with such uses. This is illustrated by the abandonment of navigation on the Colorado River when diversion dams and use of water for irrigation were needed. Navigation on the Sacramento River will be improved and its use may be increased as a result of storage releases for irrigation.

Where inland navigation may result in deep-water transportation, further improvements may be made. The only present active additional project of this type is the ship canal to Sacramento. Where navigation is limited to shallow depths, the extent of its use, even where it may be maintained, is and probably will continue to be limited.

Irrigation

Irrigation represents the use of water which has made the greatest difference in the appearance of California during the last century. Reclamation of overflow lands has also materially changed the character of the reclaimed areas but such reclamation was undertaken for the purpose of irrigating the protected lands. Writers, with the poetic touch, can, and have, painted flowery word pictures of the transformation of the arid deserts to the verdant irrigated valleys. That such poetic fancies have been inspired, in many instances, by the desire to sell the irrigated lands to reluctant settlers does not detract from the remarkable change which results where a successful irrigation project replaces a barren waste.

No final inventory of the ultimate irrigation in California has been made and none is possible except in general terms. Lands can be classified as to their agricultural adaptability. This has been done for the portions of the state where there is a probability of agricultural use. In Bulletin 3, the state found an area of 20,000,000 acres of potentially irrigable land. The investigations of the State Conservation Commission in 1912, based on a study of what would now be regarded as single-purpose projects, estimated that there were about 10,000,000 acres of agricultural lands for which a water supply could be provided. As the concept of multiple-purpose projects and comprehensive basin and statewide plans has grown, plans for conveying water from areas of surplus supply to areas of surplus dry land have increased the extent of the ultimate development that it is now expected may be reached.

In the Central Valley the need for irrigation can be expected to result in the eventual service of the full area for which a water supply can be provided at feasible cost. In some other parts of the state, such as the north coast, the ultimate irrigation will depend on the desire to irrigate as, in general, the available water supplies are in excess of the needs of the irrigable lands. In the higher areas of the Mohave and Colorado River deserts, there is no available water supply which can be delivered to these lands within any foreseeable limitations of cost.

When the present development, the future possibilities, and the type and scale of the projects now being planned are considered, it appears that California may double its present irrigated area of about 7,000,000 acres by the end of the second century of statehood.

Local Control of Water Projects

Water development in the West had generally been accomplished by local initiative or, where outside funds were secured, had remained under local management until the federal government undertook the construction of irrigation projects. Early experience in irrigation with private financing from outside sources demonstrated that outside management was not adapted to the successful operation of irrigation systems. The federal government learned this lesson early in its operating experience and adopted the policy of transferring the operation of its completed systems to organizations of their water users. This policy has been followed, except for a period during the 1940's, and is now being used again.

Turning a completed single-purpose project over to its landowners for its operation is generally a simple procedure. With the more complex conditions of present multiple-purpose projects, it may be difficult to organize a single local district which will be representative of all project uses. The federal government now retains the operation of the power developed on its projects. Present practice of the Bureau of Reclamation is to transfer the operation

of single-purpose irrigation systems to their landowners and to retain the operation of the project features serving multiple areas or purposes. Local irrigation-distribution systems have been transferred to numerous separate irrigation districts in the Central Valley Project, with the main storage and conduits retained by the Bureau of Reclamation. No transfers have been made of the power features of this project.

When the initial Central Valley Project began to approach completion, the state proposed that its operation should be transferred to the state. No workable basis for such a transfer was found and there is now little chance that this will be done. With additional divisions of the original project being constructed, there has been no stage at which the completed works could be separately operated. It is to be expected that the Bureau of Reclamation will continue to operate the main works of its Central Valley Project. Should the state construct its proposed Feather River Project, the points of contact between the two agencies can be worked out cooperatively to the benefit of both.

All plans for comprehensive projects in California are based on delivery of water wholesale at main canal side. No local distribution systems operated by the federal or the state governments have been proposed. The federal assistance in construction of local systems is handled under separate contracts and terms from the contracts for main canal deliveries. Public agencies have already been organized in nearly all of the areas proposed for service from the state's Feather River Project with which delivery contracts can be made. In southern California the Metropolitan Water District is already operating as the distributor to the coastal areas being served with Colorado River water and desires to distribute any other water supply imported to its area by the state.

To date, California has escaped controversy over the establishment of rigid federal control of its water by federal authorities similar to the Tennessee Valley Authority. The development of the past one hundred years in California is ample demonstration of the ability of local interests to manage their own water projects. There is no need for such an outside agency to replace the initiative and experience which has already accomplished so much in the state. It is to be hoped that California will continue to plan and to direct her own progress, securing the same extent of assistance from the federal government that may be extended to other states but retaining control of her own water-development projects and their policies.

Reimbursable Costs and Project Feasibility

In early single-purpose projects, the entire costs had to be met by those directly benefited by the projects. The present fancy methods of project justification based on indirect benefits had not been invented. When those directly benefited must meet all the costs with their own funds, project plans are closely scrutinized to be sure that the expected benefits will exceed the costs. When those directly benefited have to meet only a part of the costs incurred for their benefit, such scrutiny is much less complete. The directly interested participants, as well as those employed in the planning and construction of such projects, have a partisan interest in securing funds for their construction; the general interest of the taxpayer providing the nonreimbursable funds is less actively represented in such project selections.

When the federal government began to make available federal funds for the construction of irrigation and flood-control projects in California on terms whereby only a part of the costs had to be repaid, the standards of feasibility suffered an unavoidable change. Local public agencies had been unwilling or unable to provide the funds for the larger irrigation and flood-control proj-

ects in the state. Part of this refusal by local agencies was the result of the lack of financial resources. Part was the general unwillingness of areas larger than those to be benefited directly to underwrite such costs for others. Certainly the financial resources of the State of California were adequate to have enabled it to finance the initial plan for the Central Valley Project. It was so well recognized then that the voters of the state would not approve such financing that the 1933 Central Valley Project Act was carefully drawn to exclude any liability on the part of the state. As this limited the security for project financing to the credit that could be supported by project revenues, its bonds were not salable and federal funds were sought.

The federal government came into the Central Valley Project at about the same time that Congress adopted the present liberalized policies regarding costs for flood-control projects. The Central Valley Project was made subject to the Reclamation Act, which had always included repayment of construction costs. However, in the actual operations under this act, repayment had become a continuously diminishing factor through moratoria and extensions of the interest-free period of repayment. Authorizations of projects were being made where costs would clearly exceed the ability to pay under the then provisions of the Reclamation Act.

The present problems relating to projects to provide additional irrigation are mainly economic. Water supplies are obtainable and design and construction are within past practices. As the returns from irrigation per acre-foot used are limited, costs of the remaining projects have approached, and in many cases will exceed, the value of the use of water for irrigation.

There are general public benefits from the bringing under irrigation of previously unproductive lands. Such benefits are indirect and intangible, so that the extent of contribution to the costs, by others than the landowners to be served, which may be justified is not capable of definite valuation. Just as it can be conceded that some such public subsidy may be justified, it is equally evident that there is some limit in the amount of subsidy which any project should receive. Irrigation of new land or the maintenance of existing areas now using overdrawn ground-water supplies does not have an unlimited public value. The main policy problem relating to many proposed irrigation projects is, How can the subsidies that may be provided be limited to the amount justified by the actual public interest involved? Correct answers to this problem will not be reached until the general tax-paying public is more assertive of its interests and more directly represented in project selections.

Federal subsidies to irrigation have been in effect since 1902. State subsidies have not become an established practice as yet. Subsidies for the state's Feather River Project in its earlier years of operation, to be repaid from excess revenues when the project has come into full use, were included in the state's financial program in its 1955 report. The 1959 Legislature authorized what could become a state subsidy to a federal project in Senate Bill 1354 (chapter 1767). The Bureau of Reclamation has delayed part of the construction of its Sacramento canals unit until repayment contracts may be secured from areas to be served. Senate Bill 1354 authorizes the state to pay deficits that may occur in any year if revenues do not equal the repayments due. Such payments by the state are conditional on an appropriation being made for that purpose.

In a preliminary report of August 5, 1959, entitled A Study of Economic and Financial Policies for State Water Projects, a subcommittee of the Assembly Water Committee summarized the results of its extensive hearings as follows:

"The resulting voluminous transcript indicates a general feeling that project beneficiaries should substantially repay allocated project construction

costs and that subsidy, if used, should be on the local level rather than at the statewide level. In view of this attitude, an adequate test of feasibility for state projects is the logical formula that project revenues should equal project costs for vendible project services. This was found to be the best guide in pricing and marketing project vendible services. Only downstream fishing and recreation benefits and flood control were found to be nonvendible project services which, for different reasons, appeared to offer no feasible opportunity for repayment."

As discussed in chapter XIII, state policies relating to the terms of repayment of project costs in projects which the state is seeking to construct have not been defined by statute. Two construction contracts were let in 1959 for portions of the Feather River Project works which can be used to make deliveries to these units without having secured repayment agreements from the areas to be served. These actions are in conflict with the administrative policy statements issued in January 1960. If these more recent policy statements are observed, future contracts for project construction will not be let until repayment contracts from suitable water-using agencies have been secured which will assure the repayment of at least 75 percent of their costs.

Municipal Water Supply

Municipal water supplies have kept pace with population growth and water demands. In general, additions to the available supplies have been provided in advance of the needs, although in some instances, such as for metropolitan areas on San Francisco Bay, the margin at times has been small.

Estimates of the future water requirements for municipal use are as open to individual judgment as estimates of the future population. Population estimates are a field for both serious study and offhand conclusions. All estimates have agreed that large and rapid increases will take place; differences are confined mainly to the rate at which they will occur.

Municipal use is recognized legally as the highest use of water and is entitled to acquire water for its needs by condemnation from other uses. The total available water supplies in California greatly exceed the requirements for municipal use so that on a statewide basis there will always be sufficient water for municipal needs. The problems of municipal water supply are the result of the location of the larger centers of population in the state in areas where the local water supplies are limited. The costs which can be afforded for municipal water supplies have enabled water to be brought to such areas from distant sources. It is to be expected that similar conditions will apply in the future and that municipal demands will be met as they arise.

Concentrations of population occur where conditions are sufficiently favorable to attract people to such areas. The factors representing such attraction are varied. They include raw materials and a labor supply for industry, favorable climate, access to markets, favorable taxation, and good transportation. Recent experience is indicating that excessive concentration of population may produce disadvantages that exceed the advantages and there are some trends toward decentralization. People will continue to come to California only so long as, all factors considered, it is to their advantage to come; conditions in the congested population centers of southern California may become unattractive before the growth results in demands for water for municipal purposes which cannot be met. When the increase in population produces a demand for water in excess of the supplies now available, the resulting demand and the financial resources which it will represent will both enable and actually result in additional water supplies being secured. If, at the time of such needs, no unused waters remain within the distances of feasible convey-

ance, the value of the use of water for municipal purposes can be expected to result in the acquirement of waters already in use for other purposes.

Hydroelectric Power

Hydroelectric power development includes many controversial policies. The extent of use of power by all parts of the population makes the policies governing it of importance to everyone. With so much divergence in the general thinking in this field, any present discussion can only represent an individual's point of view. Eventually, some majority agreement will be reached and carried into action on each of the various items that are involved.

Without attempting to define the amount of hydroelectric resources in California, there should be general agreement that sooner or later the limit will be reached and other sources of power will be required to meet the growing demand. There is only so much water and so much fall in the California streams, so that there is a physical limitation on the amount of hydroelectric power which can be produced. Economic limitations will become effective before the physical limits are reached. In recent power installations in California, fuel generation capacity has greatly exceeded the new hydroelectric projects.

If the above conclusion is accepted, then it must follow that any power supply based on hydroelectric sources alone cannot fully meet the future power demands of the state or of its major parts. Hydroelectric power developed as a part of multiple-purpose projects or at separate sites cannot be a permanent single source for northern California and, even with additional importations of Colorado River power, for southern California.

Present hydroelectric power development in California utilizes about one-third of the estimated total potential resources. The construction of additional plants is proceeding relatively rapidly. Development should exceed half of the physically available sources within a relatively short period. As the remaining projects will be those of larger costs, additional developments may then proceed relatively slowly. Eventually, the more favorable sites will be completely used and the construction of some of the possible projects, which would not be feasible under present conditions, may be undertaken.

To date, hydroelectric power development has been made and the power distributed by privately owned public utilities with local publicly owned systems used where there was local desire for such ownership. The federal government has entered this field through the production of by-product power in its multiple-use projects.

During the 1940's, efforts were made by the Bureau of Reclamation to develop power in large amounts and to distribute it over wide areas. These plans and desires extended beyond the use of such power as a means of meeting part of the costs of projects having irrigation as their main purpose. Congress did not authorize the construction by the Bureau of Reclamation of separate single-purpose power projects nor of general transmission systems except as a part of general project operations.

The economies available to power systems serving large areas and diversified loads have been well demonstrated by experience in California and elsewhere. If centralized state or federal ownership of power should be adopted, it should be a complete system in order that it can operate economically. Any partial system can show economies only because it may secure some advantages, such as using power which is a by-product of other uses of water; by special privileges, such as exemption from tax payment; or by securing its funds at less than current costs for interest and repayment.

Nearly all of the present power development in California has been con-

structed since 1911, when the state adopted its present system of public-utility regulation. All works built since 1911 by such public utilities have been subject to approval by the state. All operating utilities have been required to install additional facilities to meet their growth in load if they were to retain their position as monopolies in their area. All rates have been subject to regulation by the state, so that the return on the capital used has been kept below speculative standards. Under these conditions, the privately owned public utilities in California have made large expenditures in increasing their facilities. If it should be decided that this method of providing for the power needs should be changed, then it is only equitable and sound public policy that the decision be made, the utilities relieved of further responsibility for expansion, and their existing works acquired at a price fair both to the utility and to the public. To date, whenever proposals for state or basin-wide state-owned public power systems have been presented to the voters of the state, their decision has been adverse to their adoption. The state Central Valley Project Act adopted in 1933 included only by-product power in a project having irrigation as its major purpose.

Reclamation and Flood Control

The major work in the reclamation of swamp and overflow lands has been accomplished. The larger part of the agricultural lands subject to crop loss by flooding have been protected against usual flood flows. Construction by local reclamation districts had passed its peak prior to the adoption of the present federal flood-control policies in 1936.

Present flood damages in California are mainly the result of the values that have been created by improvements already made. Loss of life and property did not occur on southern California streams until population settled on their flood plains. With the increasing amounts of such encroachment creating additional damages, greater costs for flood control are justified. It can be expected that a greater measure of flood protection will continue to be demanded in such areas as their development continues.

With the acceptance by the federal government of the responsibility for flood protection at federal expense and the acceptance by the state of responsibility for payment of the locally chargeable costs for rights of way, the checks and balances between costs and benefits have been largely removed. Those locally benefited by such flood-control projects advocate their construction even if the real benefits are less than the costs. No insistence for changes in present policies is apparent in the public thinking relating to flood control and it is probable that present practices will continue.

Flood-control projects having total federal costs of about $230,000,000 have been completed in California. Additional federal projects having estimated costs of about $864,000,000 are under construction or have been authorized. At the rate at which funds are being made available, about twenty years will be required to complete the presently authorized projects. Authorizations are also being sought for additional projects. The interests of the state will be best served by the early completion of the more essential projects so that their benefits may be obtained rather than by scattering of flood-control construction.

Multiple-Use Projects

The principal projects to use Colorado River water in California have been completed and are functioning. The concern of those responsible for these projects is in the uses that may be made of the water of the Colorado River in other states of its basin and the effect of such use on the water supply which

may reach California for use here. Problems relating to the use of Colorado River water in southern California have been settled with the different projects under forms of local control adapted to the functions of each project. These projects have been financed on a basis which has and will return to the federal government the principal with interest on all federal funds that have been loaned, except for the forty-year interest-free terms for the construction costs of the All-American Canal.

For the Central Valley, the end of the first century of statehood found the local single-purpose irrigation projects nearly complete and serving a large and highly developed agriculture. Construction on the initial units of a multiple-use development was underway. What may become the framework for a plan of ultimate complete development had been proposed.

The initial Central Valley Project was planned and undertaken to relieve overdraft on ground-water supplies and to prevent abandonment of lands then being irrigated. This original project is essentially complete and is accomplishing its planned purpose. Continued increase in use of water in its service area is creating additional demands and other areas in the Central Valley are also seeking service. The initial Central Valley Project has been expanded to include use of American and Trinity rivers waters and authorization is being sought to enable lands in the San Luis area on the west side of the San Joaquin Valley to be supplied. The federal Central Valley Project is proceeding toward meeting the increasing needs of the Central Valley.

Basin and Statewide Plans

A comprehensive plan for the ultimate development of the water resources of California has been proposed by the state and is available to serve as a guide in the selection of the initial units that may be built. This is a desirable status in such planning. Human foresight is inadequate to prepare a complete and rigid plan which will best serve the future needs. However, construction of present projects should be in harmony with future needs insofar as such needs can be foreseen. A reasonable middle ground is to maintain continuous study of ultimate objectives while selecting each unit for the currently needed construction. It is fortunate that the present generation has not been bound by the standards and limitations of past generations; equal opportunities should be preserved for the future generations. No generation can enforce a permanent pattern on its successors and efforts to prescribe future water development will not be successful in controlling future uses of water.

There are many undetermined items relating to the policies which should control construction and operation of basin and statewide water development. Investigations of the physical features of such plans are fairly well standardized. Water-supply records are now usually reasonably adequate, water requirements can be estimated fairly dependably, and cost estimates under any particular current price conditions can be made within the needed limits of accuracy. The engineering work in connection with such planning is difficult only as such plans are complex and extensive. In the policy field, however, the situation is much less definite.

Standards of feasibility are not well defined, except the general requirement that the value of the benefits, however they may be determined, should exceed the estimated costs. Definition of the benefits has been left to the agencies preparing such plans. There has been much variation in the past methods that have been followed. The amount of the required public investment in such projects is so large that policies relating to the sale of project services and for determining feasibility should be defined before commitments are made for the expenditures of the public funds required for their construction.

State-Constructed Projects

For the first eighty years of its development, California found no need for state construction of water projects. By 1930 it had become recognized that the needs of areas in the San Joaquin Valley could no longer be met from local sources and that the projects required exceeded the capacity of existing forms of organization. As previously discussed, the state's initial Central Valley Project was authorized and has since been constructed by the federal government. It is operating to accomplish the service planned for the state's initial project.

In recent years other areas in the San Joaquin Valley created overdrafts on their local ground-water supplies and a demand has developed for additional imported water. In southern California, the increasing use of Colorado River water created recognition that additional water would be needed by the time it could be expected that it would be made available. These pressures led to the investigations by the state which resulted, first, in the proposed Feather River Project and, later, in a water plan for the entire state.

The Legislature has provided initial funds to start the Feather River Project and has passed, for submission to a vote of the people, a bond issue for its construction. At the November 1960 election, the voters of the state will have squarely before them the decision on whether the state shall undertake construction of water projects on a major scale or whether they prefer other procedures.

The state should undertake the construction of water resource development projects only to the extent that the present projects needed have outgrown the sizes and costs which have been used in past practice. The transfer of water from the excess supply of the northern part of the state to the areas of deficiency in southern California represents a statewide project within the scope of state activity. Such development by the state is justified, provided it can be done under policies representing the over-all interests of the state. Such policies need to be defined before the construction is undertaken.

Out of the background of the last century, it should be possible to select the methods and policies which have been successful and to avoid those which have failed. If California is to embark on the construction of water projects on a major scale, such use of past experience is essential if mistakes are to be avoided. The costs involved in any such program are so large that any failure to accomplish the project objectives and to secure the expected project revenues could materially affect the state's credit. It is essential that the program of the state be soundly conceived in the interests of the whole state.

About one-half of the state will receive service from the Feather River Project. The other half has provided its own water supply at its own costs, except for works built by the federal government. The California projects of the Bureau of Reclamation are set up on a basis where the reimbursable costs will be recovered under the terms applicable to such repayment. If the entire state is to be asked to provide funds for the cost of the Feather River Project, it is incumbent on the state to secure the maximum returns from the project. Areas which have already provided funds to secure their present and future water supplies should not be taxed to provide water systems for other areas.

The starting premise of any program for state construction of water projects should be that the state will only undertake to do those things which are beyond the financial resources or general authority of agencies of smaller area. State construction should not replace local responsibilities. The state should only build those projects of sufficient general benefit to the economy of the state to justify state participation. Full return of the costs incurred

for state projects should be secured from the users of the project services up to the value of the services. No project should be undertaken by the state in which the value of the project services to the users does not equal the costs unless the remaining costs can be justified for state expenditure on a realistic valuation of the benefits to the state as a whole.

Now that water development in California has reached a nearly statewide scale, the opportunities for conflict have been greatly increased. Claims for water for irrigation, power, navigation, municipal use, fish and wild life may overlap and result in forms of class distinction between the advocates of these different uses that were unknown in our early history. The most lusty of the claimants to the use of water are the advocates of fish and wild life and of recreation. While there should be, and is, general support for these uses, where they do not restrict the recognized beneficial uses of water, there are many places in California where water allocated to fish and wild life will have to be taken from water needed for essential purposes. General interest in recreation should not be the basis for preventing productive uses of water. A reasonable balance between all uses of water is an essential of any sound state water policy.

Questions relating to the selection of the agencies used to distribute the power made available by multiple-purpose projects have been very active matters of public policy and of politics. A statutory decision has not as yet been made on the sale and distribution of power by the proposed state projects, but the issue will have to be faced and decided before project feasibility can be determined.

If the power that can be produced at the Oroville Dam is sold at its general market value, this portion of the Feather River Project can be self-supporting and provide a regulated water supply for project use. If the power from the Oroville Dam is sold below its market value, the reduction in income will have to be provided from increased charges to other uses or by state contribution. It will be to the interest of the state to sell this power at its market value, whether it may be sold to public or to private agencies. The market value will be determined by the cost of securing equivalent power from alternate sources.

In the construction of projects by the state, the main problem will be securing the full revenue which the project services can provide. To undertake construction without advance assurance of sale of project products at suitable rates is to invite financial failure. To date, the pressure for state construction has been used to secure funds and to get work under way. Less progress has been made in establishing policies that would assure project revenues.

Present Status of the Feather River Project

Any discussion of a project subject to rapid changes can only be applicable at the time it is prepared. The following comments on the present status of the Feather River Project were prepared in March 1960 and could be outdated by the time they may be published. Subject to this risk, the completion of a history of water in California should conclude with a discussion of the major pending water issue in the state.

There will be no further statutory action relating to this project prior to the vote on the issuance of bonds in November 1960, unless a special session of the Legislature to consider water matters may be called. The Governor has announced that he does not intend to call such a session.

In the absence of legislative action, clarification of the policies to be followed in the Feather River Project is limited to administrative statements

of intention. No such administrative statement was issued during the consideration of Senate Bill 1106 by the 1959 Legislature. The position of the present administration was stated in January 1960, over six months after the Legislature adjournment. Apparently, the bond act was passed before the state had reached its conclusions on how the expenditures from the bond fund would be repaid to the state by the agencies which would use project water.

Both the California Water Plan and its first project proposed to be constructed by the state (the Feather River Project) involve such large costs that their failure to secure the revenues required to meet their financial programs could seriously affect the credit of the state. A statutory declaration of the repayment conditions and feasibility standards, similar to the federal Reclamation Act, should be a prerequisite to the undertaking of state project construction. Under the status at present, and probably at the time of the November 1960 vote on the project bonds, assurance to the voters on how project costs will be repaid will be limited to administrative statements by the present incumbents. Such statements are subject to later change by those making them and are not binding on their successors.

The Feather River Project will provide water for several different areas. The general conditions relating to each can be separately discussed.

Upper Feather River Storage Projects

The authorized Feather River Project now includes five reservoirs on the upper Feather River drainage area. The total estimated cost of these reservoirs is about $6,000,000, equal to about three-tenths of 1 percent of the total estimated cost of the entire project. Funds for their construction were appropriated by the 1959 Legislature.

The Department of Water Resources called for bids and has let the contract for the construction of the reservoir of the Frenchman project on Little Last Chance Creek. This project will provide supplemental water for lands in the Last Chance Water District in Sierra Valley. In Bulletin 59, the total costs were estimated to be $1,695,000—divided about 52 percent to the cost of the dam, 35 percent for lands and relocations, and 13 percent to recreation facilities. The costs for lands and relocations were considered to be a "responsibility of the state" (paid by the state). The annual costs allocated to irrigation were estimated to be $30,200. The new water yield was estimated to be 12,000 acre-feet per year, to be sold at $2.50 per acre-foot. This sale would meet the part of the total costs allocated to irrigation, leaving the state to meet the annual costs of $59,000 for the lands and relocations and for the constructed recreational facilities. The construction contract for this project was let and construction is proceeding without having secured a repayment contract from the lands expected to use the stored waters.

Oroville Reservoir

As previously discussed, the Oroville Reservoir appears to be capable of repaying its costs from the sale of the power it can produce. These costs, exclusive of the expected federal contribution for flood control, are currently estimated to be $390,000,000. If the power produced is sold at its market value, it is estimated that the power revenues in the early years of operation can more than meet the costs and provide some profit to be used to reduce prices of water for other uses. On this basis, the construction of Oroville Reservoir can be justified financially, even if diversions from the Delta should be delayed. Oroville Reservoir will need to be operated to provide maximum water conservation benefits when the Feather River Project is in

full use; it should be built as a part of the Project so that its operation can be coordinated with the water demand.

Feather River Service Area

The nearest uses of storage released from Oroville Reservoir will be for lands diverting from the Feather and the Sacramento rivers and in the Delta. Much of the area dependent on Feather River is now irrigated. Some of these areas need supplemental water and there are additional areas which will eventually be irrigated. The state has estimated these demands, for what it terms the Feather River service areas, as a total of 970,000 acre-feet per year and has provided water for such service in the plans of the Feather River Project. The state has also estimated the ability of these lands to pay for water for irrigation to be $8.50 per acre-foot. Under the Delta rate, proposed in the January 1960 policy statements, the charge for project water in this area would be $3.50 per acre-foot.

The desirability of serving these areas dependent on Feather River with Feather River water before diversions may be made to distant areas for irrigation is self-evident. These lands have similar crop adaptability and ability to pay for water to the lands for which the Feather River supply may be exported for irrigation in the San Joaquin Valley. The cost of serving such local areas will be much less than the cost of exportation.

Lands in the Feather River service area will be able to meet the probable costs that may be allocated to their service. While this ability to pay should be recognized, the ability to collect from these lands is another matter. In order to secure payment for the use of any stored water, it is essential that the rights to the natural flow of each diversion be defined so that the diversion of released storage can be identified. No adjudication of present rights has been undertaken. As such a determination of rights is a lengthy process, it does not appear probable that income from sale of stored water to the Feather River service area will be available in the early years of project operation. This conclusion is supported by the record of the Bureau of Reclamation in its operation of the Shasta Reservoir, where a similar condition exists relating to diversions from the Sacramento River. After some twenty years' operation of Shasta Reservoir, there has been no definition of direct diversion rights which can be used to identify diversions of stored water and the Bureau has not secured revenues from Sacramento Valley areas from their diversions of its releases of Shasta storage. While there has been much discussion and extensive investigations that would be useful in adjudicating present diversion rights from the Sacramento River, actual hearing procedure has not been undertaken. The state has not acted as yet on the applications to appropriate water for storage in Shasta Reservoir; hearings on such applications were started in 1959. Greater expedition in the case of Oroville Reservoir is not indicated by the Sacramento River record to date.

In view of this record, in financial plans for the Feather River Project reliance should not be placed on securing revenue from the sale of water to the Feather River service area within the time when such revenue will be needed to meet bond charges.

Aqueducts to San Francisco Bay Areas

The Feather River Project includes north and south Bay aqueducts and a proposed Pacheco Pass tunnel. All of these facilities would serve lands in the San Francisco Bay area and part of the central coast. Each of these aqueducts is separable from the main Feather River Project, as their omission

would not affect the construction of the main project. This enables each aqueduct to be considered separately and a decision reached on its construction based on its own service.

Conditions relating to these three diversions vary. For the North Bay Aqueduct, eagerness to contract for water has not been apparent to date.

The South Bay Aqueduct will serve areas of present ground-water draft adjacent to the eastern and southern shores of San Francisco Bay where salt-water intrusion is a continuing threat. Although these areas are rapidly being urbanized, irrigation is now and for some time will probably continue to be a large user of water. In part of this area, San Francisco now sells water for municipal purposes and has indicated its ability and desire to supply additional demands. The extent to which the municipalities in this area may secure their future needs from San Francisco or from the South Bay Aqueduct has not been determined.

The state has let contracts for the construction of the upper portion of the South Bay Aqueduct. These works will enable water to be pumped through Altamont Pass for delivery into the Livermore Valley where natural stream channels can be used to convey water for percolation in the areas of ground-water overdraft adjacent to Alameda Creek and its tributaries. No contracts for use and payment for this water were made prior to the letting of this construction contract. Negotiations for such contracts are now proceeding, based on the principles announced in the January 1960 policy statements.

Pacheco Pass Tunnel

The Pacheco Pass tunnel is still in the investigational stage. In addition to the investigations which have been made by the state, the Bureau of Reclamation is making a cooperative study with the prospective users of water which might be diverted through the tunnel. The proposed tunnel would divert near the San Luis Reservoir and convey water through the Coast Range east of Gilroy. It could serve lands in San Benito, Santa Cruz, northern Monterey, and Santa Clara counties. The earlier plans for the South Bay Aqueduct were based on its extension into these areas.

A tunnel under Pacheco Pass might be built as a part of the state's Feather River Project or as an addition to the federal San Luis Project.

Main Aqueduct

South of its San Luis Reservoir, the Feather River Project has two main types of service and two main areas to be served. Service, primarily for irrigation, in the upper west side and southern end of the San Joaquin Valley is one of these functions and areas. Conveyance to southern California, mainly for municipal and industrial use, is the other. The proposed coastal aqueduct to San Luis Obispo County is an additional service which would not be considered unless the main project is also to be constructed.

In round figures, the Feather River Project is planned to provide nearly 3,300,000 acre-feet of mean annual water supply for diversion from the Delta. Of this total, about 400,000 acre-feet have been allotted for delivery to the North and South Bay aqueducts and the Pacheco Pass tunnel, 1,300,000 acre-feet for areas in the upper San Joaquin Valley, 1,350,000 acre-feet to southern California, and 250,000 acre-feet to the central coastal aqueduct.

The ultimate demands in both the upper San Joaquin Valley and in southern California, as now estimated by the state, will exceed the amounts of water

which each area will secure from the Feather River Project. It is estimated that the planned water supply from the Feather River Project will meet the demands of these areas until about 1985, when additional water will be needed.

The service area of the state's project in the upper San Joaquin Valley includes the lands in the San Luis Unit of the federal Central Valley Project and additional areas extending to Wheeler Ridge in the southern end of the Valley. Besides the land now irrigated in the San Luis area, there is some present development in the Devil's Den. In recent years there has been a large expansion of irrigation in the Wheeler Ridge area. The remainder of the lands to be served from the Feather River Project in the upper San Joaquin Valley are undeveloped. The present irrigation uses the local ground-water supply which has only limited sources of recharge and becomes overdrawn under any extensive draft. As discussed in chapter VI, these ground-water conditions have been known and were generally recognized prior to the present irrigation in these areas.

The state cannot afford to accept responsibility for providing an imported water supply to any area which may choose to knowingly mine its existing ground water. Present users could, and presumably have, secured full return on their costs for their irrigation development from their past use of the underlying ground water as it has lowered. Plans for the future irrigation of these areas should be based on what can be accomplished from now on. If water can be imported at a cost within their ability to pay, these lands should be included in any state project.

The feasibility of the state's entire Feather River Project is based on the assumption that southern California is both able and willing to pay the prices for water that will be required to repay the cost of its delivery. In the preliminary draft of Bulletin 78, dated May 1958, entitled "Feather River and Delta Diversion Projects," the Department of Water Resources based its estimates of the prices which would be secured for the water to be delivered in areas south of the San Luis Reservoir on the cost of delivery. This report states, "At the present time the pricing schedule for water to be delivered under the San Joaquin Valley–Southern California Aqueduct System has not been nor can it be established." Consequently, the report was necessarily based on the assumption that each area would meet the costs of its service. The report further states that "the full cost of water at the main aqueduct involved in delivering water to each service area, including full recovery of capital cost with interest, is the proper basis for estimating economic demands for supplemental water for purposes of aqueduct system selection and preliminary design." This is the basis of repayment defined in the Department's statement of policy of January 1960.

The estimated costs for water used in Bulletin 78, as the expected prices to be paid by the contracting users, varied from $10 to $24 per acre-foot for delivery to areas in Kern County; the differences being the result of the location and elevation of the different areas to be served. For the central coastal aqueduct, the similar costs used were $26 to $49 per acre-foot. The costs for the Antelope-Mojave area were $38 per acre-foot, and for the southern California coastal plain and coastal San Diego County were $43 per acre-foot.

These estimated costs are within the ability to pay for water used for municipal or industrial purposes. They are generally higher than the price at which large amounts of water have been sold for irrigation use. All of these prices for water used in Bulletin 78 and in the other state reports are delivery from the main conduits and do not include the costs for local distribution. Such local systems will materially increase the costs of final delivery to the individual water user over the wholesale prices used by the state.

Material submitted to the Senate Fact Finding Committee on Water presented by the Department of Water Resources on August 20, 1959, included the results of the Department's estimate of the payment capacity for agricultural water. For areas in Kern County the estimated ability to pay was $14 per acre-foot in northern Kern County and $22 in southern Kern County.

In the January 1960 policy statement of the Department, the cost allocated to the service of the area from Avenal Gap to Buena Vista Lake was $11.50 per acre-foot delivered plus an annual lump sum payment to meet capital charges of $4,700,000. The expected use of water in this area, under full project use, from other department reports, is 592,000 acre-feet. The sum of the delivery rate and the cost of capital charges represents a total cost of about $19.50 per acre-foot.

For the area from Buena Vista Lake to Wheeler Ridge, the January 1960 policy statement proposed a delivery rate of $13 per acre-foot, with a capital charge of $2,610,000 per year. A delivery of 325,000 acre-feet per year to an area extending from Buena Vista Lake through the Tehachapi Mountains had been used in other Department reports. If all of this water is used in the Buena Vista Lake to Wheeler Ridge area, the total charge for water would be about $21 per acre-foot.

These prices it is proposed to charge for water in these Kern County areas exceed the Department's estimated ability to pay in northern Kern County and closely approach the similar limit in southern Kern County.

The ability and willingness of the users of water for irrigation in the upper San Joaquin Valley to pay the proposed prices for their service from the Feather River Project have as yet not been tested. Contract negotiations prior to the November 1960 vote on the project bonds may furnish at least a partial answer to the willingness to undertake such repayments. If the needed volume of water sales should not be obtainable at the prices required to meet the costs of this service, greater prices will have to be met by municipal and industrial users in southern California, if the project costs are to be repaid without cost to the state. Surplus power revenues to meet irrigation costs will not be available in the Feather River Project as they are available and are being used in the federal Central Valley Project.

Of the total repayment of $57,020,000 needed to meet the fixed charges on the aqueduct from the Delta to southern California, exclusive of the branches to the San Francisco Bay and central coast areas, as given in the January 1960 statement of the Director of Water Resources, $49,020,000, or 86 percent, was assigned to be paid by areas in southern California, This assignment of fixed charges to southern California is 71.5 percent of the total fixed charges of all areas to be served by export from the Delta. On this basis, the aqueduct from the Delta could be started and some of its branches built as soon as the required repayment contracts covering the planned use in southern California have been secured.

Alternate Programs

There is a basis on which classes of service not able to meet their allocated costs in a multiple-use project may be included without detriment to the services which are able to meet higher costs. This is to plan the project for the services having ability to pay to serve their uses only and then to add any other uses which may be able to meet more than the incremental costs resulting from their inclusion.

On such a basis, the Feather River Project might be set up, with the Oroville Reservoir on a self-financing basis from the sale of power. An aqueduct to southern California to provide water for its municipal and industrial

needs could be planned and its costs estimated. The incremental construction and operation costs for the enlargement of this project to serve other uses and areas could be estimated to determine which of such uses might be able to meet their incremental costs. Such an incremental cost basis may be the only means available by which volume sales of water for irrigation may be secured in the upper San Joaquin Valley without material subsidies for the cost of such service.

The primary incentive of the Feather River Project is to provide additional water for municipal and industrial water in southern California in time to meet its increasing needs as its population grows. Irrigation of the west side and southern lands in the upper San Joaquin Valley is in the public interest only if the areas to be served can meet the costs of their service or if the subsidy required from outside sources, federal or state, is less than the resulting indirect benefits on a statewide or national basis. With the current surplus agricultural production, there is no present over-all need for additional irrigated areas. If a project can be built for municipal and industrial uses in southern California at costs which such uses can afford to pay, the demands now being forecast for the times of delivery and the amounts of such supplies can be met without being dependent on the use of water for irrigation in the upper San Joaquin Valley.

If no method for constructing the proposed state's Feather River Project on a basis on which its total costs would be repaid by the users of its service is available, another alternate plan might be the enlargement of the capacity of the proposed San Luis Unit of the federal Central Valley Project to deliver water at its southern boundary to be received there and conveyed to southern California by agencies representing the users of municipal and industrial water. Such an undertaking at this time by southern California, with its present resources, would be comparable with its construction of its Colorado River aqueduct at the time this earlier system was built.

Relation of Feather River Project to San Luis Unit of Federal Central Valley Project

Service from the Feather River Project in the San Joaquin Valley is closely related to the proposed San Luis Unit of the Central Valley Project of the U.S. Bureau of Reclamation. The Bureau's Unit would serve about one-half of the area the state proposes to serve in the San Joaquin Valley. This is the area of large present development extending from the San Luis Reservoir to Kettleman Hills, which now uses the greatly overdrawn west-side ground waters. There is no necessary conflict between the state and federal agencies regarding which should serve this area. The first question to be answered by each agency is the feasibility of the service which it proposes.

The federal San Luis Unit proposes to secure its water supply from present surplus flows in the Delta and storage from the federal Central Valley Project reservoirs. The state proposes to use the same surplus Delta supply and storage from Oroville Reservoir. If the federal government constructs the San Luis Unit and the state the remainder of the Feather River Project, the total water supply made available will exceed that which will be available for the state's Feather River Project alone.

For a federal project, the construction costs would be interest free over a total repayment period of probably fifty years. For a 3 percent interest rate, this represents a subsidy of about one-half of the cost. For higher interest rates, the extent of the interest subsidy is increased. In its last report (Bulletin 78) the state used an estimated interest rate applicable to state financing of $3\frac{1}{2}$ percent. Recent sales of state bonds have been at interest rates approaching 4 percent.

As previously discussed in chapter XII, for its estimated costs of the main canals for its San Luis Unit the federal interest subsidy for a 4 percent interest rate would be about $135,000,000. If, as expected, the federal government also constructs the local distribution system, the total interest subsidy to the landowners would be about $300,000,000.

The interest subsidy represented by federal construction in the amounts indicated above may provide the final answer to the question of which agency will construct the San Luis Unit. If the federal government, under its reclamation policies, will make the contribution represented by its interest subsidy, it can be expected that eventually it will be accepted both by California and by the local landowners. For the state, such acceptance would reduce both its initial construction cost and the interest which would have to be paid to secure funds for such costs. There is no necessary conflict in the physical systems needed for federal construction of its San Luis Unit and the state's plans for the remainder of its Feather River Project.

Construction of its San Luis Unit by the federal government would make the lands to be served subject to the acreage limitations of the federal reclamation law. These limitations restrict ownerships of land to be supplied with project water to 160 acres per individual or 320 acres for a husband and wife. The lands in the San Luis Unit are adjacent to productive oil fields and are generally now in large ownerships. To date, the larger landowners have not indicated a willingness to reduce the size of their land holdings.

Summary

The preceding discussion illustrates the complications of the present Feather River Project and its financing by the state. Individual opinions will vary regarding the correctness of some of the statements that have been made. Such differences are the result of the incompleteness of the present project plans relating to the revenues it can secure and the policies to be followed in seeking such revenues. Regardless of these differences of opinion, there should be general agreement that, like any other creditor, the state should insist that the willingness and ability of the users of project services to meet the project costs should be known and enforceable repayment contracts should be secured before the state issues its general obligation bonds to meet the construction costs.

There should also be a clear understanding of the water supply that is being provided by the works it is proposed to build with the funds to be made available by the pending bond issue, the amount of additional water which will be required within the life of the bond issue to replace water now available which may be used in the areas of its origin, and the expected source and cost of such replacement supplies.

Normal procedure in project investigation and progress would have been to determine the general policies under which it would have been to the interest of the state as a whole to use its credit to construct water projects of statewide scope and then to test proposed projects by these standards. This procedure was not followed in the Feather River Project. A physical plan was presented and was authorized by the Legislature in 1951. A financial program was proposed in 1955, and in 1959 the Legislature passed Senate Bill 1106, placing a bond issue of $1,750,000,000 on the ballot in November 1960 for action by the voters. The lack of statutory standards governing repayment and public insistence on knowing the policies the state administration proposes to follow, if the bonds should be approved, resulted in a belated statement of intended policies by the Governor and the Director of Water Resources in January 1960. This statement lacks statutory authority and differs from

that used in the 1955 report. It is subject to change at any time by the incumbents of the present administration or their successors. In voting on these bonds in November 1960, unless a special legislative session may have been called and may have acted, the voters will only have the January 1960 administrative statements or their later changes on which to rely in reaching their conclusions regarding the extent to which the costs of the Feather River Project will be repaid by the users of the project services. The progress that may be made in securing actual repayment contracts between January and November 1960 will furnish a tangible basis for conclusions regarding the financial soundness of the project.

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